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Is the SUN an oddball star?

Conventional wisdom says the Sun is ordinary. But astronomers are struggling to find stars like it. p. 24

Bob Berman on attention-deficit astronomy p. 14

A huge prominence arcs above the Sun's limb during this 1999 solar eruption. Astronomers are trying to learn whether other Sun-like stars display similar activity.

Mysteries of the Magellanic Clouds p. 30

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Vol. 38 • Issue 6

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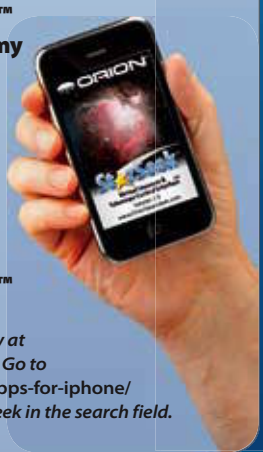

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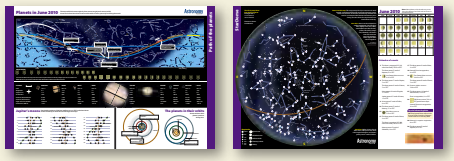

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JUNE

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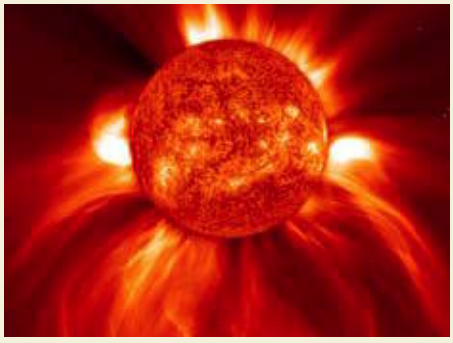
ON THE COVER

Near the peak of the Sun's previous cycle, large prominences were common. But the Sun has since calmed down and shows few signs of returning to robust activity.

FEATURES



24 COVER STORY
Is the Sun an oddball star?
Accepted wisdom holds that the Sun is an ordinary, run-of-the-mill star. But astronomers are having a hard time finding true solar twins.
BRUCE DORMINEY

30 **Mysteries of the Magellanic Clouds**
They produced the nearest supernova in 300 years, are connected by a giant stream of matter, and may collide with the Milky Way. **BILL ANDREWS**

36 **The Sky this Month**
Jupiter meets Uranus at dawn. **MARTIN RATCLIFFE AND ALISTER LING**

44 **Illustrated: What makes stars tick?**
Inside most stars is a chaotic and high-energy environment. How do changes inside stars coincide with what we see? **LIZ KRUESI; ILLUSTRATIONS BY ROEN KELLY**

48 **Ask Astro**
The Moon's movement.

50 **Join the CCD revolution**
Choose one of these top 23 cameras to help you capture the universe. **MICHAEL E. BAKICH**

50

56 **How an amateur astronomer captured a black hole scoop**
When Stephen G. Cullen imaged Cygnus X-1 in May 2009, he discovered the effect this black hole has on its neighborhood.
STEPHEN G. CULLEN

58 **Amplify your view of the night sky**
Night Vision Astronomy's Binocular Photon Machine will triple your telescope's aperture through electronics. **TOM TRUSOCK**

COLUMNS

14 **Strange Universe**
Attention-deficit astronomy.
BOB BERMAN

15 **Observing Basics**
Our galaxy in a nutshell.
GLENN CHAPLE

16 **Evening Stars**
Astro-businesses: A way of inspiring.
DAVID H. LEVY

60 **Secret Sky**
Phantasmagoria: transient luminous events.
STEPHEN JAMES O'MEARA

IN EVERY ISSUE

8 **This Month in *Astronomy***
Astronomy announces Out-of-this-World Award winner.

11 **Web Talk**

12 **Letters**
Christmas sights...

18 **Astro News**
New study questions supernova origins.
Why early galaxies formed so many stars.
Pulling apart a stellar WASP.
Here comes the Sun — in high def.

62 **Telescope Insider**

63 **New Products**

64 **The Cosmic Grid**

68 **Advertiser Index**

69 **Deep-sky Showcase**

70 **Reader Gallery**

WEB EXTRA

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Astronomy (ISSN 0091-6358, USPS 531-350) is published monthly by Kalmbach Publishing Co., 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Periodicals postage paid at Waukesha, WI, and additional offices. POSTMASTER: Send address changes to *Astronomy*, 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Canada Publication Mail Agreement # 40010760.

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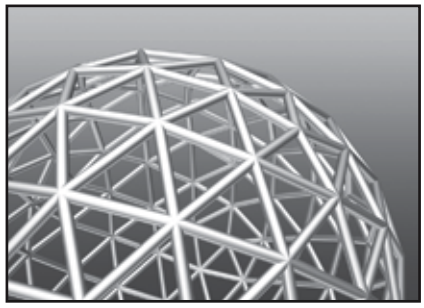

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This Month in *Astronomy*

by David J. Eicher

Astronomy announces Out-of-this-World Award winner

Astronomy magazine has selected the Amateur Observers' Society of New York (AOS) as the winner of the 2009 Out-of-this-World Award for outstanding programming. The group, founded in 1965, holds its monthly meetings at Nassau Community College on Long Island in Garden City, New York.

AOS distinguished itself from the nearly 30 entries this year with the breadth of its "Reach for the Universe" programs, providing something fun and interesting for everyone. Its events feature more than just beautiful images and demonstrations — AOS goes the extra mile and gets the public involved as well. It plans to use the award money to update the failing decades-old telescope mount that controls its 14-inch telescope at the Susan F. Rose Observatory. Normally open to the public every clear Saturday night, this resource will soon become unusable without replacement, rendering many of AOS's events impossible. The group will also install a motorized dome at the observatory, saving the members both valuable time and energy.

AOS gets the public involved, especially young astronomers. Linda Prince

AOS reaches out to the public with a variety of other events as well. Its children's workshops offer early opportunities for solar observing, weekly presentations and observing sessions give amateurs a gentle welcome into the hobby, and telescope clinics help current scope owners get the most out of their equipment. The variety and depth of AOS's "Reach for the Universe" programs ensure that anyone who might even be remotely interested in astronomy in the New York area has a place to go, resources to use, and a friendly, knowledgeable staff to provide help.

Astronomy's Out-of-this-World Award typically rewards ongoing programs sponsored by an educational or civic organization. The award recognizes a group's sustained efforts to involve its local community in the science and hobby of astronomy. AOS is the fourth winner since the award debuted in 2006. Last year's honors went to the Cincinnati Observatory Center, and the 2007 selectee was the Aldrich Astronomical Society in Winchendon, Massachusetts. In 2006, *Astronomy*'s editors chose Celestial North, Inc., an astronomy club in Freeland, Washington, to win the inaugural award. The winner receives $2,500 from *Astronomy* magazine.

Once again this year, we had a very difficult decision in choosing the winner. There's a lot of wonderful outreach going on all over this country, and all over the world, as our international submissions prove. Everyone who entered deserves congratulations and thanks for doing so much to promote the hobby and science of astronomy.

Look for an announcement in the coming months for the 2010 Out-of-this-World Award, and make sure you enter your organization to vie for money to help its outreach activities.

Yours truly,

David J. Eicher
Editor

Astronomy

Volume 38, Number 6

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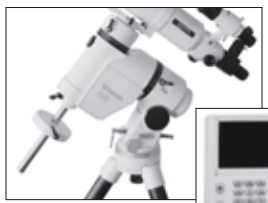

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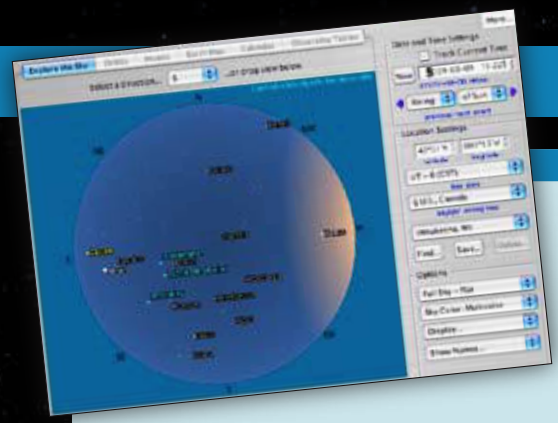

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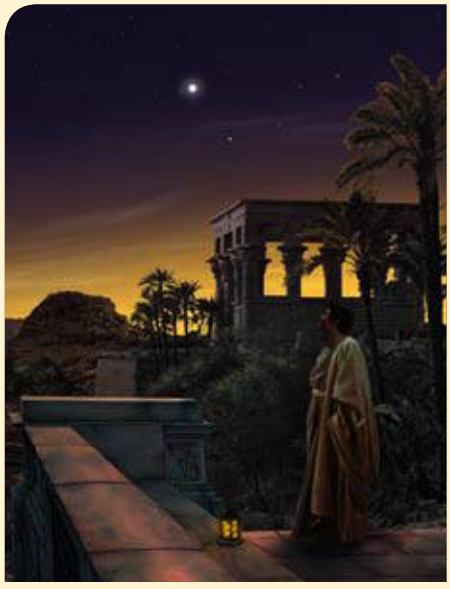
Christmas sights …

Thank you for your January 2010 article, "What was the Star of Bethlehem?" As a Christian interested in astronomy, I long ago gave up my subscriptions to science magazines due to the rude and degrading treatment Christians receive from most of them.

While we may not all believe the same things, science is the pursuit of fact and truth, and should be all-inclusive. The discussion should still be civil and respectful. Congratulations to Senior Editor Michael E. Bakich for being brave enough to write an article that addresses a fascinating Biblical issue in such a complete way, and for doing so in a respectful and neutral manner.

You have restored my hope that people out there can still do that, and that magazines aren't afraid to publish it. I look forward to my next issue of *Astronomy*. — **Joe Korpela,** Welches, Oregon



Whatever the Star of Bethlehem may or may not have been, Michael E. Bakich's story exploring the possibilities proved intriguing to some readers, and pointless to others. Ron Miller for *Astronomy*

… and frights

Quelle Horreur! I opened my January issue of *Astronomy*, a magazine of once-reputable science, and saw an article wondering, "What was the star of Bethlehem?"

Do even you, *Astronomy*, pander to the superstitious mythology of the Christian right of the United States, without even a tongue-in-cheek giggle? Characters in allegories don't have real birthdays, as if it even needs to be said. As for what the star may have been, you may want to consider the comet that supposedly arrived after the assassination of Julius Caesar, another J. C. who was probably the basis for the whole Jesus story.

Come on! If you're going to venture outside the realm of science, at least stay in the area of verifiable history. — **Kerry Summer,** Saint-Alphonse-de-Granby, Quebec

Colliding names, galaxies

Every time I hear the name Milkomeda used to describe the imminent collision of the Milky Way and Andromeda galaxies, I want to scream. It sounds terrible, not to mention self-centered.

Andromeda Way is so much better. I think it's time for a change. — **Howard "Skip" Medlock, Jr.,** Lubbock, Texas

"Average fans" count, too

David J. Eicher's February editorial, "*Astronomy* magazine is on a mission," missed the mark.

Although asking customers for feedback is commendable, the quotes in the editorial appear to be mostly from individuals with professional connections or who are hard-core amateurs. Those of us who are neither could have provided much more elegant feedback.

We read *Astronomy* because we are fascinated with the photos, the science, the never-ending search for answers, and the enthusiasm expressed in all the articles. Please continue to provide this, not just for the professionals or hard-core amateurs, but also for the average reader. You know, the one who relies on your magazine to quench the thirst for ongoing universal knowledge and who finds the subject just plain amazing. — **Roger Lloyd,** Helena, Montana

Start'em early

I leave my old *Astronomy* magazines in a spot accessible to my 5-year-old daughter, so she can peruse the pictures at her leisure. One of her favorite tomes is a children's astronomy book with drawings of the constellations, so she's become familiar with the "Great Bear" and the "Great Dog" labels for the star pictures in the sky.

I must share my amusement at her excited exclamation the other day as she pointed at the constellation Piscis Austrinus in the September 2009 "Stardome" pullout: "Oh mommy look, the Great Mouse!" — **Barbara Farr,** Massapequa, New York

Corrections

In "How astronomers probe weather on exoplanets," (page 37 of *Astronomy*'s February issue) the prism should have been rotated 90° away from the reader, standing on its triangular face.

In Stephen James O'Meara's March column, the graph displaying the Moon's apparent size should begin at phase –0.5, not at phase –.05. Also, the disk Kevin Krisciunas uses to measure his eyes' correction factor is 3.58 inches (91 millimeters) in diameter.

In "Closing in on cosmic-ray sources" (page 28 of *Astronomy*'s February issue), the fourth sentence in the second paragraph should read: "The particles have an electric charge, so galactic magnetic fields alter their paths." — ***Astronomy*** Editors

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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Strange Universe
by Bob Berman

Attention-deficit astronomy

Discover ways to entice astro-newcomers in this fast-paced world.

A decade ago, I suggested ways to dazzle visitors with a backyard astronomy show. Well, the universe hasn't changed much since then. But we have. Attention spans have shrunk.

My grandmother used to tell long-winded stories, and we kids would listen in disbelief: "And then I met the waitress. Her name was Judy. Well, it could have been Lucy. No, wait, I'm sure it was Judy. She wore a red dress but no necklace. She probably left it home that day. Or maybe she lost it. Anyway … " And I'd yell, "Jeez! Grandma! Get to the point!" Her friends spoke that way, too. Tectonic plates shifted during their stories.

Times have changed. Old flicks like *Casablanca* show actors reciting dialog for a full minute at a time. That's gone for keeps. Today's average movie cut is 4 seconds. Camera shots change about 15 times per minute. Zip-zip. Meanwhile, the busy urban population grows. The pace keeps speeding up.

Many people are still into leisurely pastimes like reading, yoga, chess, and astronomy. But enticing new — especially younger — people often requires finesse.

That's why SLOOH, the online observatory I'm involved with, now has its telescopes change targets every 5 minutes instead of 10. It's that attention-span business. What a contrast from a subzero winter night 35 years ago when I stared at Saturn for 3 hours. Moments of steady seeing revealed exquisite detail through my Criterion RV-6. That was the traditional way to observe planets.

Because most astrophysicists don't know the night sky, the backyard astronomer is the go-to person when folks are curious about the heavens. TV science specials are nice, but "hands on" still has no equal. If friends or family know you're into astronomy, you'll have one shot at hooking them. So, how can you win over attention-deficit newbies?

Here's my sure-fire backyard telescope program. It works. Usually.

Start with something bright and dramatic. The Moon is perfect at any phase but full. Include a low-power view. Say nothing at first; let the visceral impact sink in. Then supply one cool fact. It's most likely a waxing Moon, so you could tell them its shadow line, the terminator, is where sunrise crosses each big crater in about 5 hours.

Then go to a globular cluster. Everyone loves them. But first downplay their expectations. Tell them the Hercules Cluster (M13) is faint and that with luck they might be able to glimpse individual suns in this city of a half-million stars. Wham! They'll be amazed.

The mantra should be OM: Obvious and Magnificent.

Change the scene dramatically with a colored binary. Albireo in Cygnus never disappoints. Again, keep them engaged: "Star colors are delicate pastels. See if you can tell which star is gold and which is blue." Then watch their reaction. "I see it! I see the colors!" Sure, it's psychomanipulation. But involvement makes them feel like successful observers rather than passive onlookers.

You'll be tempted to show a faint, challenging object. Don't. Tonight, the mantra should be OM: Obvious and Magnificent. Presented with a galaxy, the visitor too often says, "That faint blur, is that what I'm supposed to see?" Their voices ooze disappointment. Now they need psychotherapy.

In real life, people never spend prolonged amounts of time staring at faint objects. This is unfamiliar behavior for them. If you must offer a galaxy, prep them first. Warn about its dimness. Hand them a photo so they know what to look for. The Whirlpool and NGC 4565 are wonderful this time of year, but only if you have a large scope and dark skies. Remember: This first observing experience is very influential.

After five or six objects, close it up. Finish with a brilliant spectacle. Never use up all your favorites in the beginning so that the finale is a dim smudge. End with Jupiter or Saturn. Learn from Hollywood: The best comes last, and leave them wanting more.

Showing a beginner Andromeda or Mars should be a misdemeanor. It approaches the felony of making them watch vacation videos. Over the years, your visitor has seen fabulous photos of those two objects, and such familiarity creates high expectations. Through your scope, teensy Mars and colorless M31 will look like garbage.

Unlike low-light images at the eyepiece, magazine photos are sharp and colorful. You cannot compete. Don't try. Instead, play to your instrument's strengths, which reveal glories like M13 and lunar craters to perfection.

Do all this and Zeus, the classical god of the sky and noted ADD sufferer, will bless you when he's not distracted. You'll earn a wreath. For you've converted friends and family — even your teenage geeklets — to astronomy.

Browse the "Strange Universe" archive at www.Astronomy.com/Berman.

Contact me about my strange universe by visiting **skymanbob.com.**

Observing Basics

by Glenn Chaple

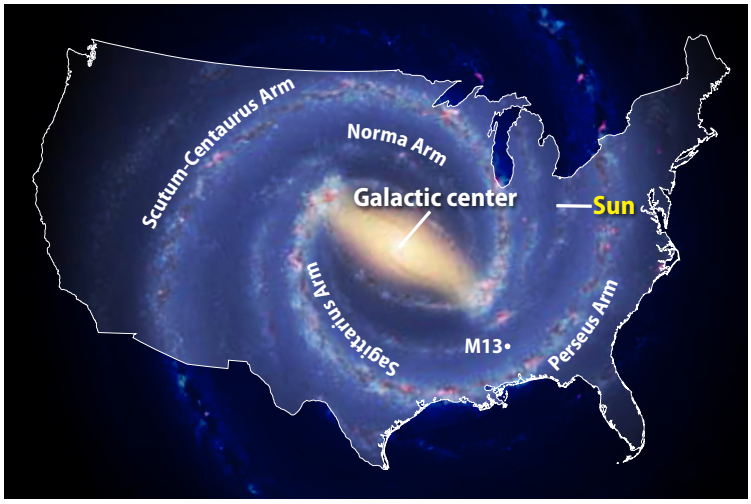
Our galaxy in a nutshell

Use distance scales to better understand our place in the Milky Way.

Last month, we scaled down a few currently visible solar system bodies, winding up with a basketball-sized Sun whose most distant major planet, Neptune, is a marble a half mile away. This month, we go galactic, leaving the solar system behind to explore our Milky Way Galaxy.

I received an e-mail last year from Newburgh, Indiana, astronomer/educator Joseph Caruso. Caruso has come up with an interesting way to demonstrate the size of the Milky Way. He writes, "In order to visualize the enormity of the Milky Way, it's convenient to superimpose it onto a map of the United States." Caruso uses a scale where the United States is approximately 3,000 miles (4,828 kilometers) across while the Milky Way spans 120,000 light-years. A light-year in the Milky Way therefore equals 132 feet (40 meters) on the map. The center of the Milky Way is in Topeka, Kansas. This puts the solar system (26,000 light-years from the galactic center) in Columbus, Ohio, some 650 miles (1,046 km) away.

At this scale, the whole solar system is only 2 inches (5 centimeters) across, and almost all the stars we see with the naked eye (out to about 1,000 light-years) are confined to a 25-mile (40 km) radius around Columbus. The Sun is a minute speck about one-twentieth the thickness of a sheet of paper! Let's see how this scale translates to some currently visible deep-sky sights.



Astronomy: Kellie Jaeger, after Joseph Caruso; Milky Way: NASA/JPL-Caltech

If the Milky Way were the size of the United States with the galactic center in Topeka, Kansas, our solar system would be 650 miles away in Columbus, Ohio.

Arcturus

This golden-yellow 1st-magnitude star glimmers high in the evening sky after June sunsets. Arcturus is 37 light-years away. A giant star nearing the final chapters of its life, it is 25 times as large as the Sun. On our U.S. map, the aging star is a dot comparable to the size of the period at the end of this sentence. It lies within the Columbus city limits, a little less than a mile from the solar system. Were we to depart from Joe's scale for a moment and represent the Sun by something more readily visible like a marble, Arcturus would be a 15-inch-wide (38cm) beach ball almost 2,500 miles (4,025 km) away.

The Ring Nebula (M57)

The Ring Nebula is the most-observed planetary nebula. It's 2,300 light-years away, so its light began the earthward journey around the time the early Greek astronomer/mathematician Aristarchus of Samos proposed a Sun-centered solar system. Its bright portion has a diameter of 0.9 light-year. Our scaled-down Ring is 119 feet (36m) across, twice the length of a volleyball court (remember, the entire solar system spans 2 inches), 57 miles (92 km) south-southwest of Columbus.

The Hercules Cluster (M13)

This magnificent stellar swarm appears as a small, luminous 6th-magnitude spot near the Keystone of Hercules. Light crossing the 25,100 light-year void separating us from M13 left during the time of the last Neanderthals. M13 is thought to be 145 light-years across. On the U.S. map, this great cluster is some 625 miles (1,000 km) south-southwest of Columbus. Hundreds of thousands of stars, represented by barely visible specks, fill a spherical area 3.6 miles (5.8 km) wide.

What if we continue Caruso's scale beyond the Milky Way? The Andromeda Galaxy, the nearest major galaxy to the Milky Way, would hover about 62,500 miles (100,580 km) away (a little more than one-fourth the real distance to the Moon). The Virgo cluster of galaxies, which includes the giant elliptical galaxy M87, is now 1.5 million miles (2.4 million km) away. Even though Caruso's scale has sized down the cosmos 235 trillion times, what astronomers have been able to see in our universe would still stretch outward a whopping 325 million miles (523 million km)! No wonder we feel humbled when we gaze upward at the night sky.

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com. Next month: Astronomy books of yore. Clear skies!

Browse the "Observing Basics" archive at www.Astronomy.com/Chaple.

Evening Stars
by David H. Levy

Astro-businesses: a way of inspiring

Take advantage of some of the best skygazing equipment the world has ever seen.

From simple telescopes to observatory domes, from magnificent eyepieces to the latest in CCD technology, it's hard to overstate the role that businesses play in promoting astronomy.

I first looked through a telescope September 1, 1960. Although Skyscope, the company that built the 3.5-inch f/11 scope, has long since gone out of business, it left behind an impressive legacy. That first night's look evolved into a career of comet discovery, thousands of observations of variable stars, and enjoyment of solar and lunar eclipses.

As competitive as the telescope industry is today, at its center lies a common beating heart. When I started, Celestron and Meade were almost a decade away from their mutual drive to revolutionize telescopes. We had a choice of reflectors and refractors; the Schmidt-Cassegrain Telescope, now ubiquitous, was hardly a dream in its designer's eye back then. By 1978, Celestron's C8 had become the fastest-selling telescope in history, and by the early 1980s, Meade Instruments had come out with its own line. Today, Meade's Autostar has evolved to the point where it rivals professional mountaintop telescopes for pointing and tracking accuracy. These instruments are efficient, well-constructed, strong, and easy to use.

With each technology upgrade, telescopes become more accurate, more fun to use, and more interesting. I remember attending an evening talk years ago where the audience sat spellbound as Celestron founder Tom Johnson reviewed the history of his company since it started as a reseller of Japanese telescopes. Meanwhile, Meade, also founded as a reseller, grew to eventually become the largest telescope company in the world. Despite these difficult economic times, Meade still pushes the envelope on new development.

Even a casual look through this magazine will illustrate the tremendous variety of astro-retailers competing for amateur astronomers' dollars. Some of the more interesting companies include Starizona, whose specially designed HyperStar lens allows users to photograph large fields of view down to 19th magnitude or fainter in exposures as short as 30 seconds. Fitting Meade or Celestron telescopes, this lens is a superb piece of engineering.

Other firms also go where no one has gone before. JMI Telescopes, to use a favorite example, has a line of binocular telescopes based on the theory that if each eye looks through a telescope, the combined view is far better than twice a single telescope. I love mine. It's especially useful when a satellite wanders through the system's field; it seems to hang in space like a lamp swinging across a room. This system is one of the best modifications to basic telescope design in the past 401 years. When the telescopes work properly, the view is simply amazing. With any telescope, looking at the Moon is a precious treat, but through a binocular telescope the Moon swells to a practically three-dimensional appearance. Unforgettable!

With all these companies, I do recommend a good dose of patience. All are helpful and provide staff willing to spend many hours working with you so that you can work easily with their products. Often in our modern digital age, a trick or two helps to get a product to work with a particular computer. If you have such troubles, give the support staff a chance to help. In all likelihood, they can get things working for you.

Also, do something I don't do: When walking around your telescope, be careful. The number of times I have tripped over cables and cords is legion, and often these falls have rendered equipment inoperative. I've done this since 1961, when I plunged my Skyscope into a snow bank, snapping the cast-iron platform. Luckily, the company replaced it, and it still works to this day.

The years to come will undoubtedly offer new varieties of products. Some will not be of use to you, but others will make your observing life easier. It may be easy to criticize those trying to earn a living from a product, but without them our avocation would still be where Galileo left it centuries ago.

A crowd of unruly telescopes threatens to overtake David Levy. From left: Miranda, a homemade 26-inch Newtonian; Gemini, a 10-inch JMI binocular telescope; Obadiah, a 16-inch Meade Schmidt camera; Flaire, a 14-inch Meade SCT; Samwise, a 10-inch Meade Schmidt-Newtonian; Pegasus, a Cave 8-inch Newtonian; and Clyde, a Celestron 14-inch SCT. Wendee Levy

Browse the "Evening Stars" archive at www.Astronomy.com/Levy.

NEXT MONTH
in the July issue

NASA/ESA/S. Beckwith (STScI)/the HUDF Team

Astronomy
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Hubble's top 5 science discoveries
From dark energy to exoplanets to black holes, the Hubble Space Telescope helps astronomers understand some of the biggest mysteries of the universe.

How we'll explore Pluto
Cold, dark, and virtually unknown, distant Pluto will finally feel the spotlight when NASA's New Horizons spacecraft arrives in 2015.

How sky surveys will revolutionize astronomy
Two new telescopes will repeatedly image the cosmos in minute detail, revealing myriad asteroids and supernovae. They also will help determine dark energy's properties.

All about the North America Nebula
Scan this giant nebula through binoculars or a telescope, and you'll find a lot more than just dazzling beauty.

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Precisely general A new experiment, described in the February 18 issue of *Nature*, proved Einstein's general theory of relativity correct more than 10,000 times as precisely as ever before.

For the latest news on space discoveries, spacecraft missions, and sky events, visit **Astronomy.com/news**

Astronews

NASA/The Hubble Heritage Team/STScI/AURA

Alien clusters. New research shows that globular clusters, such as M80 (shown above in a Hubble photo), may have originated in another galaxy and later joined the Milky Way.

Alien clusters pervade galaxy

New research shows that the Milky Way Galaxy welcomes immigrants with open spiral arms. In an upcoming *Monthly Notices of the Royal Astronomical Society* paper, a team of astronomers led by Swinburne University of Technology professor Duncan Forbes shows that several of our galaxy's star clusters originated somewhere else.

"Many of the stars and globular star clusters we see when we look into the night sky are not natives, but aliens from other galaxies," says Forbes. "They have made their way into our galaxy over the last few billion years."

Astronomers had previously theorized that globular clusters (containing between 10,000 and several million stars) might have migrated to the Milky Way, but it was hard for scientists to tell the natives from the newcomers. Forbes' team used data from the Hubble Space Telescope to record the age and chemical properties of various star clusters to identify "telltale clues as to their external origin."

"We determined that these foreign-born globular star clusters actually make up about one-quarter of our Milky Way globular star cluster system," says Forbes. This means the Milky Way received tens of millions of new stars from globular clusters alone.

The finding also indicates that our galaxy may have "cannibalized" as many as six more dwarf galaxies than previously thought. "This will have to be explored further," Forbes says, "but it is a very exciting prospect that will help us to better understand the history of our own galaxy." — **BILL ANDREWS**

20 Here comes the Sun — in high-def

21 Pulling apart a stellar WASP

22 Galaxies caught in the act

23 X marks the (collision) spot

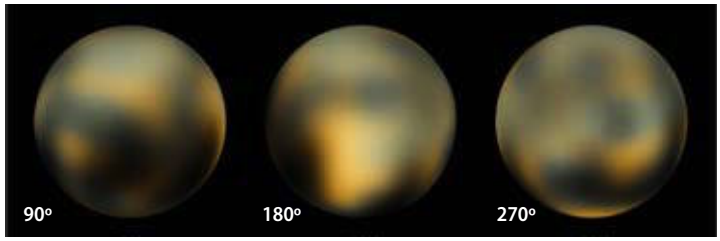
23 Why early galaxies formed so many stars

Detailed images of Pluto released

New images of Pluto show dramatic color and brightness changes. From 1954 until 2000, Pluto exhibited a consistent dark-amber color. But images taken with the Hubble Space Telescope in 2002 and 2003 show that Pluto became 20 to 30 percent redder in those few years. Pluto's moon Charon hasn't changed color.

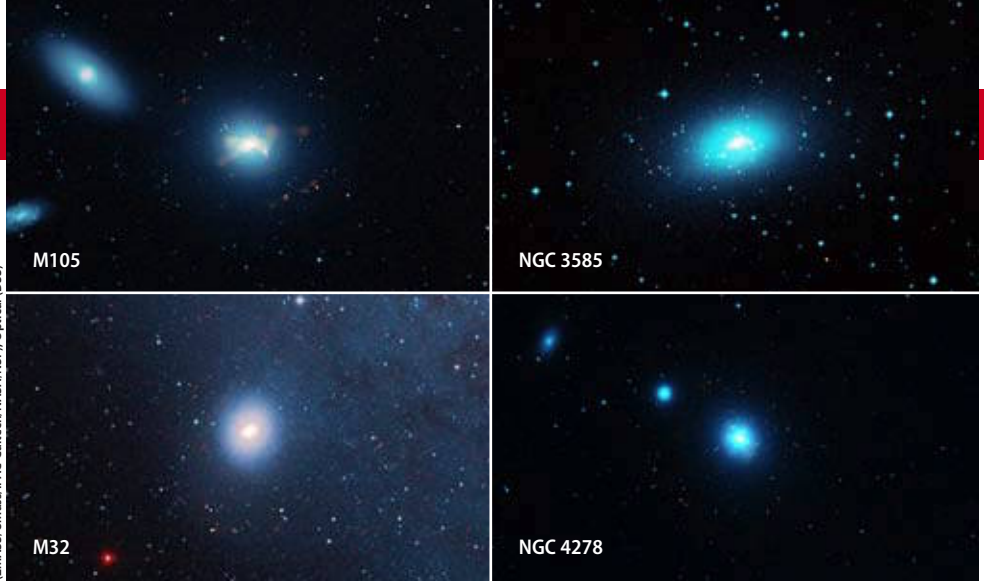
Astronomers think Pluto's dramatic color changes are from changing seasons on the dwarf planet. The atmosphere is effective at moving frost around on Pluto's surface, so there's likely a circulation pattern altering the appearance.

These maps will remain the sharpest of Pluto until 2015, when the New Horizons probe approaches the world. Researchers are using the Hubble images to help plan where to point the craft and how long exposures should be. — **LIZ KRUESI**



NASA/ESA/M. Buie (Southwest Research Institute)

Unexpected changes. Pluto's molasses-colored surface changed between early data and these images, taken in 2002 and 2003. The degree markings indicate longitude. At 180°, the bright area is a carbon monoxide patch.



X-ray (NASA/CXC/MPA/M. Gilfanov & A. Bogdan); Infrared (2MASS/UMass/IPAC-Caltech/NASA/NSF); Optical (DSS)

Merger makers? **Scientists analyzed the X-ray emission in elliptical galaxies and the bulge of one spiral. Four of the ellipticals are shown here (they are the center objects in each X-ray, optical, and infrared composite image). The astronomers found less X-rays than expected.**

New study questions supernova origins

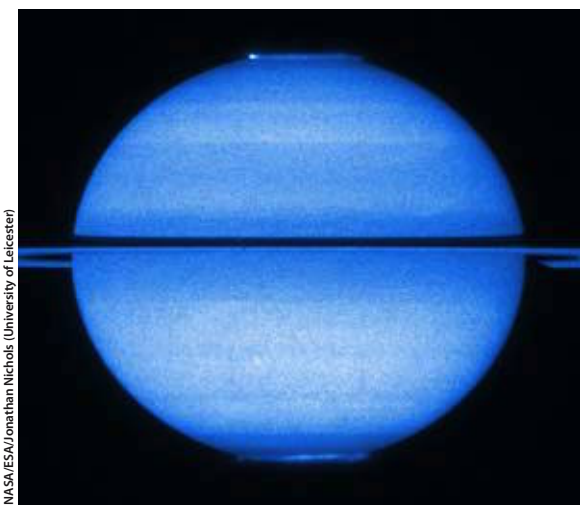
For decades, astronomers have wondered what causes a particular type of cosmic explosion called a type Ia supernova. The leading theory says a white dwarf star steals material from its red giant companion until the white dwarf reaches a specific mass and explodes. Another theory suggests that two white dwarf stars spiral in and eventually merge with an explosion of energy; this is the merger theory. Research published in the February 18 *Nature* suggests mergers may contribute to more supernovae than previously thought.

Scientists from the Max Planck Institute for Astrophysics used a fresh approach to figuring out what method makes type Ia supernovae. The accretion scenario would emit X-rays for millions of years before the white dwarf explodes. In the merger scenario, X-rays would be detectable only just before the merger occurs.

The researchers calculated the expected number of supernovae in a galaxy, and therefore the number of required white dwarfs. Then they determined how much X-ray emission they should see if the accretion scenario leads to those supernovae.

The scientists used Chandra X-ray Observatory data to analyze five elliptical galaxies and the bulge of the Andromeda Galaxy. They found 30 to 50 times less X-ray emission than expected, which means that in the observed galaxies only a few percent of supernovae likely originate from accretion. However, the team observed mostly elliptical galaxies, and supernovae occur far less frequently in such galaxies. They plan to focus on spiral galaxies in future studies.

Type Ia supernovae are the observational tools cosmologists have used to show that the universe's expansion is speeding up. Therefore, understanding what causes these stellar explosions has an effect on many areas of astronomy. Mario Livio, of the Space Telescope Science Institute and not associated with the *Nature* study, pointed out that the idea of dark energy existing is unchanged with this result. — **L. K.**



NASA/ESA/Jonathan Nichols (University of Leicester)

Spying Saturn's light shows

Rare glow. **As Saturn approached its equinox in early 2009, the Sun lit both poles. The Hubble Space Telescope took advantage of the opportunity and captured a series of images of the planet and its ring system edge-on; astronomers with Hubble released this picture February 15, 2010. Northern and southern aurorae are visible at both poles. This phenomenon is a result of particles from the Sun — forming the solar wind — interacting with Saturn's magnetic field. Earth has a similar glow at its poles. — L. K.**

QUICK TAKES

GAMMA-RAY CELEBRATION
The American Astronomical Society awarded the 2010 Rossi prize February 1 to three scientists and the High Energy Stereoscopic System collaboration for helping image high-energy gamma rays.

SUPER SUNSHADES
The James Webb Space Telescope's sunshield passed its design review, making it ready for manufacture, NASA announced February 2.

SPACE IN 3-D
Astronomy & Astrophysics announced February 9 that it will publish new 3-D maps of the interstellar gas lying within 1,000 light-years of the Sun.

FLYING BY PHOBOS
The European Space Agency announced February 16 that its Mars Express spacecraft started flybys of martian moon Phobos.

GOODBYE DR. GORDON
Bill Gordon, the designer and manager of Puerto Rico's Arecibo Observatory, died of natural causes February 16 in Ithaca, New York, at the age of 92.

SPACE SCIENCE FAIR
NASA held the Next-Generation Suborbital Researchers Conference February 18–20 to explore new ways to further space-, life-, and Earth-science experiments.

TARGET: TEMPEL 1
NASA's Stardust spacecraft adjusted its trajectory for encountering comet Tempel 1 next year to better ensure high-quality images of the object, NASA announced February 18.

TOUGH CHOICES
The European Space Agency announced February 19 three mission candidates for two future missions: mapping dark energy, searching for habitable exoplanets, and exploring our Sun's mysteries.

NEW EARTH SEARCH
A February 3 paper in *Nature* describes a new calibration method for ground-based infrared telescopes to better study the atmospheres of exoplanets.

BIG STAR? BIG DEAL
A February *MNRAS* paper shows that magnetic fields play important parts during massive stars' births, implying that low-mass and high-mass stars may form more similarly than suspected.

Optical (ESO/WFI); Submillimeter (MPIfR/ESO/APEX/A.Weiss et al.); X-ray (NASA/CXC/CfA/R.Kraft et al.)

Jet setter. **Some astronomers now think the jets that radiate from certain supermassive black holes (such as Centaurus A, above) are the result of that black hole's retrograde spin.**

Retrograde spin may cause black holes' jets

As mystifying as supermassive black holes can be, the jets of plasma some of them eject into space remain among the biggest unsolved mysteries. These jets have tremendous influence, from controlling how nearby stars form to determining a galaxy's evolution. Understanding them would be a great step forward in astronomy.

Dan Evans of MIT's Kavli Institute for Astrophysics and Space Research may not have figured the jets all out, but he's made an important first step. In a paper published in the February 10 edition of *The Astrophysical Journal*, Evans and his team conclude that these jets form outside the supermassive black holes that have a retrograde spin, meaning they spin in the opposite direction as their accretion disks. (All black holes, with or without jets, have disks of matter called accretion disks spinning around them.)

Using data from the Suzaku observatory, Evans' team studied a supermassive black hole with jets 800 million light-years away named 3C 33. They never found an expected X-ray pattern called the "Compton reflection hump," which results from light reflecting off the accretion disk.

This implies a gap between the black hole and its accretion disk, which would result from a retrograde spin. The gap causes magnetic fields to pile up and produce the energy necessary to fuel a jet. — **B. A.**

Here comes the Sun — in high-def

At 10:23 A.M. EST February 11, an Atlas V rocket lifted off from Cape Canaveral Air Force Station on Florida's Atlantic coast. The rocket's precious cargo: the Solar Dynamics Observatory (SDO). SDO promises to launch a revolution in scientists' understanding of the Sun and its complex magnetic field.

A series of engine burns in the following weeks helped to circularize the observatory's track. Eventually, it will settle into a geosynchronous orbit some 22,300 miles (35,900 kilometers) above Earth's surface.

SDO will watch the Sun in unprecedented detail nearly continuously for at least 5 years. The observatory will image the Sun every few seconds with a resolution approaching that of an IMAX movie. And every 10 seconds, SDO will take full-disk solar images with a resolution 10 times better than that of a high-definition television.

The resulting stream of data will allow scientists to understand why and how the Sun's magnetic field changes. SDO will determine how the Sun generates its field and will map its structure. It will also analyze how magnetic fields release stored energy, the process that creates explosive solar flares and coronal mass ejections.

Such knowledge will help scientists predict solar storms and their intensities. These storms not only create beautiful aurorae in Earth's sky, but they also can wreak havoc on power grids, communications, and other technologies. Such storms also pose a threat to astronauts aboard the International Space Station.

To accomplish all this, SDO carries three science instruments: the Extreme ultraviolet Variability Experiment (EVE), the Helioseismic and Magnetic Imager (HMI), and the Atmospheric Imaging Assembly (AIA).

EVE measures fluctuations in the Sun's output of radiation with wavelengths between the ultraviolet and X-ray parts of the electromagnetic spectrum. HMI maps the Sun's surface magnetic fields and peers beneath the solar surface using a technique called helioseismology. And AIA contains four telescopes that take eight full-disk photographs of the Sun's surface and atmosphere every 10 seconds — capturing gas at temperatures ranging from 20,000 to 20 million degrees.

Up, up, and away. **The Solar Dynamics Observatory blasts into space February 11 on top of an Atlas V rocket.** United Launch Alliance/Pat Corkery

SDO transmits about 1.5 terabytes of data to Earth every day, equivalent to streaming 380 full-length movies. Unlike most satellites, SDO doesn't record this data onboard. Instead, it continuously beams the information to a dedicated ground station near Las Cruces, New Mexico. The observatory's geosynchronous orbit allows it to maintain continuous contact with the ground station. — **RICHARD TALCOTT**

Quasar quasar A February 20 paper in *The Astrophysical Journal* describes the first evidence of a binary quasar (the bright center of an active galaxy that produces lots of energy) created by a pair of merging galaxies.

New view of a stellar cradle is born

Baby star factory. **Astronomers using the European Southern Observatory's (ESO) Very Large Telescope snapped this image of NGC 3603, a giant stellar nursery. This region frantically makes stars and is the closest such starburst region to us at about 20,000 light-years away. Within the central cluster sits a binary system with stars weighing 89 and 116 times the mass of the Sun. The larger star is the most massive currently known in the Milky Way. ESO released this stunner February 3. — L. K.** ESO

The universe's oldest stars, uncovered

The European Southern Observatory (ESO) has finally discovered how to locate some of the oldest stars outside the Milky Way, after years of unsuccessful attempts.

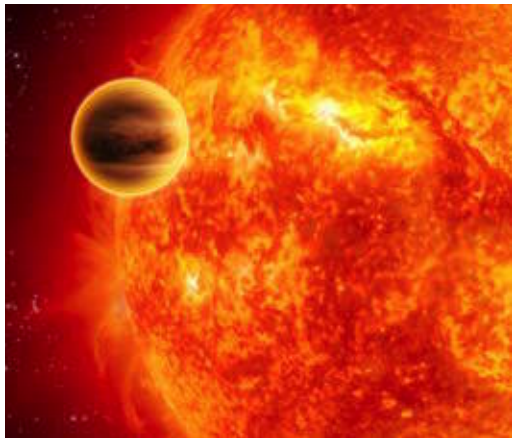
"We have, in effect, found a flaw in the forensic methods used until now," says Else Starkenburg of the University of Groningen, lead author of the paper reporting the study in an upcoming issue of *Astronomy & Astrophysics*. "Our improved approach allows us to uncover the primitive stars hidden among all the other, more common stars."

Those primitive stars are truly old: They're thought to have formed shortly after the Big Bang some 13.7 billion years ago. That makes them unlikely to contain elements heavier than hydrogen and helium because it takes supernovae (the deaths of massive stars) to create the heavier elements, referred to as metals in astronomy.

Astronomers have found such primitive stars almost exclusively in the Milky Way, despite expecting to find them in other galaxies. Starkenburg's team carefully re-examined data from ESO's Very large Telescope to determine just how subtle the differences were in detecting primitive metal-poor stars versus regular metal-poor stars.

Come out, come out. **Scientists had looked for primitive stars in nearby galaxies, such as the Fornax dwarf galaxy (above) for years, but only recently developed the tools to best find those ancient suns.** ESO/Digitized Sky Survey 2

Armed with this new knowledge and ever-higher precision instruments, Starkenburg is confident these ancient stars will no longer prove so elusive. "From now on, there is no place left to hide," she says. **— B. A.**



Withering away. **This artist's illustration shows exoplanet WASP-12b in its unusually close orbit to its sun. Scientists now suspect the star's tidal forces are so strong that they're pulling loose the planet's atmosphere.** ESA/C. Carreau

Pulling apart a stellar WASP

One of the most extreme planets known just became a little extremer. A paper in the February 25 edition of *Nature* describes why the exoplanet WASP-12b — already remarkable for its unusually fast and tiny orbit — is abnormally large, and how it's likely losing its atmosphere to its host star, WASP-12.

When astronomers discovered WASP-12b in 2008, some 600 light-years away, its characteristics were surprising. The gas giant orbits its star in just 26 hours from a mere distance of about 1 million miles (1.6 million kilometers), 36 times closer than Mercury's average distance to the Sun.

WASP-12b is also some 80 percent bigger than Jupiter and 50 percent more massive. The paper's authors suggest the exoplanet's large size is a result of tidal distortions from its star.

"This is the first time there is direct evidence that the internal heating (or 'tidal heating') is responsible for puffing up the planet to its current size," says Douglas N. C. Lin, one of the authors and a professor at the University of California at Santa Cruz. The tidal forces are also so strong that they're stripping off the planet's atmosphere at the rate of about 6.6 billion tons per second.

This material won't actually fall into the star, but will instead form a disk as the material spirals slowly inward. The planet will likely disappear completely in about 10 million years. **— B. A.**

Keep it up, Cassini! NASA announced February 3 that it would extend the Cassini-Huygens mission to explore Saturn and its moons to 2017, nine years beyond its original end date.

Come together. **This Hubble image shows four nearby dwarf galaxies as they slowly combine to form a larger elliptical galaxy. (The bright object at center is an unrelated star.)** NASA/ESA/J. English (University of Manitoba)/ The Hubble Heritage Team (STScI/AURA)

Galaxies caught in the act

Astronomers have discovered a local and recent example of galactic behavior typical of billions of years in the past. A paper in February's *Astronomical Journal* describes a quartet of small, ancient spiral galaxies only 166 million light-years away that is gradually coming together, becoming a single large elliptical galaxy.

"Most other dwarf galaxies like these interacted billions of years ago, but these galaxies are just coming together for the first time," says Sarah Gallagher of the University of Western Ontario, lead author of the paper. "This encounter has been going on for at most a few hundred million years — the blink of an eye in cosmic history. It is an extremely rare local example of what we think was a quite common event in the distant universe."

Astronomers have known for decades that the galaxies, members of Hickson Compact Group 31, have been gravitationally pulling on each other. The galaxies are relatively small and so close together that all four could fit within the Milky Way Galaxy.

Gallagher suggests that they may only now be coming together because they lie in a part of the universe with lower-than-average density. **— B. A.**

Astronomy announces Out-of-this-World Award winner

Astronomy magazine has selected the Amateur Observers' Society of New York (AOS) as the winner of the 2009 Out-of-this-World Award for outstanding programming.

AOS distinguished itself with the breadth of its "Reach for the Universe" programs, providing something fun and interesting for everyone. Its events feature more than just beautiful images and demonstrations — the society goes the extra mile and gets the public involved as well. AOS plans to use the award money to update the failing decades-old telescope mount that controls its 14-inch telescope at the Susan F. Rose Observatory.

Normally open to the public every clear Saturday night, this resource will soon become unusable without replacement, rendering many of AOS's events impossible. The group will also install a motorized dome at the observatory, saving the members valuable time and energy.

"We're very excited to win this award, and very appreciative," says the group's activities director, Linda Prince. She says it's due to the "many dedicated volunteers. ... Thank you so much!"

Astronomy's Out-of-this-world Award typically rewards ongoing programs sponsored by an educational or civic organization. AOS is the fourth winner since the award debuted in 2006.

BRIEFCASE

Quake rocks Earth

NASA researcher Richard Gross calculated that the February 27 earthquake in Chile may have shortened Earth's day by about 1.26 millionths of a second. The magnitude 8.8 earthquake also may have shifted Earth's axis by 2.7 millionths of an arcsecond, which is equivalent to 3 inches (8 centimeters). — L. K.

Cassini finds more on Enceladus

On February 23, Cassini scientists announced new finds on Saturn's moon Enceladus from the November 21, 2009, flyby. In one mosaic of images, astronomers saw 20 previously unknown geysers. The flyby also obtained the best 3-D image yet of a fissure that sprays ice particles, water vapor, and organic compounds. — L. K.

Gamma rays hint at cosmic rays

NASA's Fermi Gamma-ray Space Telescope detected gamma rays for the first time in three supernova remnants. Scientists have long thought supernova remnants accelerate high-energy particles called cosmic rays. As these particles collide with interstellar gas (such as that in the remains of a supernova), they produce gamma rays. This finding provides evidence that such remnants do in fact accelerate cosmic particles. — L. K.

25 years ago in *Astronomy*

June 1985

In the June 1985 issue of *Astronomy*, frequent contributor Michael W. Carroll gave readers a glimpse into "The First Colony on Mars." In painstaking detail, he described how the future pioneers will overcome the hurdles of longtime weightlessness, landing on the Red Planet, and making a home there.

"It's time to leave our home … and go to our new home, the New World," Carroll wrote of the future colonists. And who will they be? "The men and women who will inhabit the first permanent colonies on Mars are among today's toddlers."

Sadly, as the staff of *Astronomy* who were toddlers 25 years ago can attest, a human colony on Mars remains a long way off. Still, the dream of exploring another planet continues to thrive, so perhaps it is today's toddlers who will see it happen.

June 2000

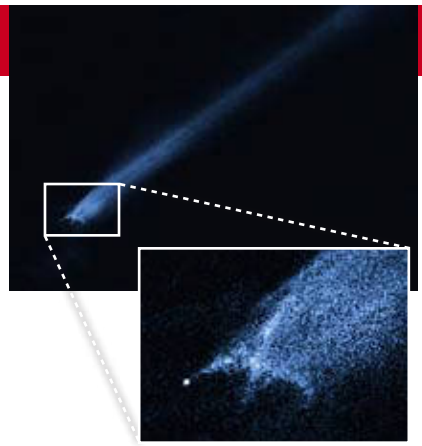
10 years ago in *Astronomy*

In the June 2000 issue of *Astronomy*, David Cortner explained the latest way to study the stars in "Learning the Southern Skies Online." The University of Western Sydney in Australia had recently started a program that allowed students to earn a master's degree through coursework conducted entirely over the Internet, and Cortner traveled there to get a firsthand, behind-the-scenes look at the Astronomy Internet Master's.

In these days of Kaplan University and the University of Phoenix, it may be easy to forget how new and exciting such a program would have been. "In the beginning," Cortner wrote, "an Astronomy Internet Master's will be an unusual credential whose novelty will spark interest." **— B. A.**

Seeing new details on martian craters

Aging landscape. The European Space Agency released this image of part of the Sirenum Fossae region in Mars' Southern Highlands February 3. The Mars Express spacecraft snapped the picture while orbiting, showcasing an area about the size of Belgium at about 95 feet (29 meters) per pixel. The largest crater, at the bottom right, marks this area as ancient because big craters form only rarely in modern times and smaller craters appear "within" it; the crater at the top left, however, is relatively young, as indicated by its sharp, uneroded outlines. — **B. A.** ESA/DLR/FU Berlin (G. Neukum)



X marks the (collision) spot

Asteroid tail? When astronomers saw a comet-like object amid a gaggle of asteroids, they weren't sure what to make of it. But after the Hubble Space Telescope released this image February 2, which shows an odd X pattern at the object's nucleus, they suspected that it was the product of a head-on collision between asteroids. Although astronomers have long suspected that the asteroid belt hosts such powerful crashes, this could be the first time scientists have ever seen one. — **B. A.** NASA/ESA/D. Jewitt (UCLA)

Why early galaxies formed so many stars

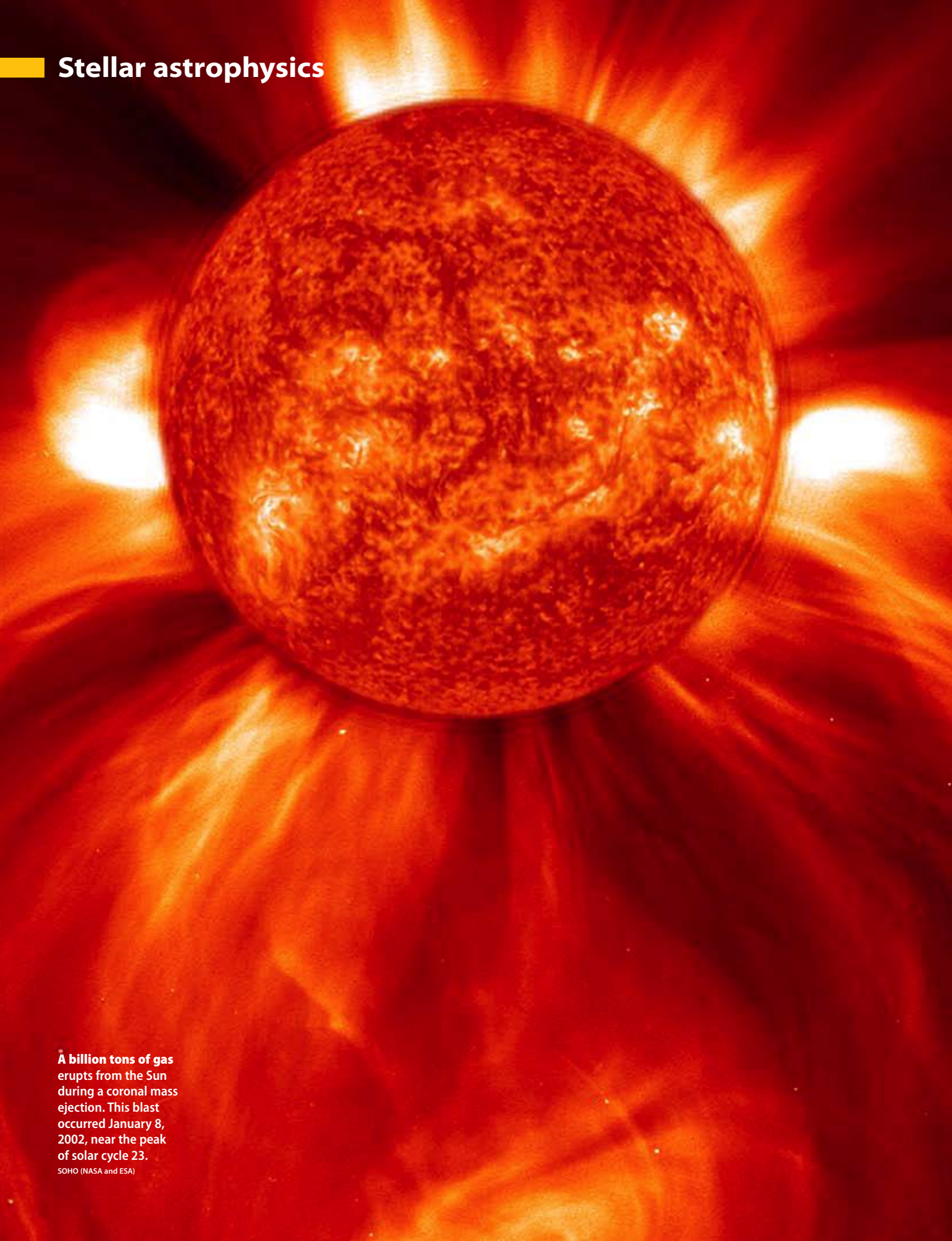
Galaxies in the young universe formed stars at least 10 times faster than today. For years, astronomers have theorized that the higher star-formation rate was a result of more raw material in earlier times. Linda Tacconi of the Max Planck Institute of Extraterrestrial Physics in Garching, Germany, and colleagues have found evidence that this theory is correct. Their results appeared in the February 11 issue of *Nature*.

While studies in the past have found similar results, those studies observed rare and luminous objects. Tacconi and colleagues instead studied 19 normal galaxies that existed when the universe was 3 to 5.5 billion years old (corresponding to redshifts of about 2.3 and 1.2, respectively).

Stars form from cool molecular hydrogen gas, but directly detecting this type of hydrogen gas is difficult. However, carbon monoxide and molecular hydrogen appears in an equal ratio throughout galaxies. So the team measured the width and shape of emission lines from carbon monoxide molecules, which traces the distribution of molecular hydrogen.

Gas guzzlers. Galaxies in the early universe appear to have had up to 10 times as much material to form stars as those today. These early galaxies likely contained many star-forming regions, similar to NGC 2467 shown here. Gemini Observatory/Travis Rector (University of Alaska, Anchorage)

"We have been able to demonstrate that massive normal galaxies at z ~ 1.2 and z ~ 2.3 had 5 to 10 times more gas than what we see in the local universe," says Tacconi. Now the question is where the extra gas comes from. Tacconi adds that it "must have been continuously replenished by accretion from the [surrounding] dark matter halos." Many models agree and also point to accretion as a source of the gas. — **L. K.**



A billion tons of gas erupts from the Sun during a coronal mass ejection. This blast occurred January 8, 2002, near the peak of solar cycle 23.
SOHO (NASA and ESA)

Is the SUN an oddball star?

Accepted wisdom holds that the Sun is an ordinary, run-of-the-mill star. But astronomers are having a hard time finding true solar twins. **by Bruce Dorminey**

I'm OK. You're OK. But the Sun? It could be having a midlife crisis.

Like aging parents anxiously taking stock of their adult offspring, solar physicists must continually tweak their theoretical models to explain our middle-aged star's sometimes confounding behavior. Most solar researchers confidently declare our Sun to be perfectly normal; average even. But then in the next breath, they protectively argue that the Sun is unique or peculiar in its own right.

Among the questions these researchers continually ask are: How normal is the Sun for a star of spectral type G2? Is its behavior fine-tuned for life, or is our evolution here something of a fluke? And if the Sun is average, where are all its analogs among the hundreds of billions of stars in our galaxy?

For decades, astronomers have hunted for a solar twin that would best match the chemical and astrophysical characteristics of our own aging star. By definition, a solar analog is a spectral type G star of any age. By contrast, a solar twin must be nearly the same age. It also must have a mass, chemical composition, and temperature nearly identical to the Sun's.

Frequent contributor **Bruce Dorminey** *is a science journalist and author of* Distant Wanderers: The Search for Planets Beyond the Solar System *(Springer, 2001).*

Spots before our eyes

In time, our true stellar soul mates will provide a basis of comparison to help scientists fine-tune their current solar models. Until then, a large part of our solar-learning curve lies in the varying magnetic forces that surround the Sun's 11-year sunspot cycles.

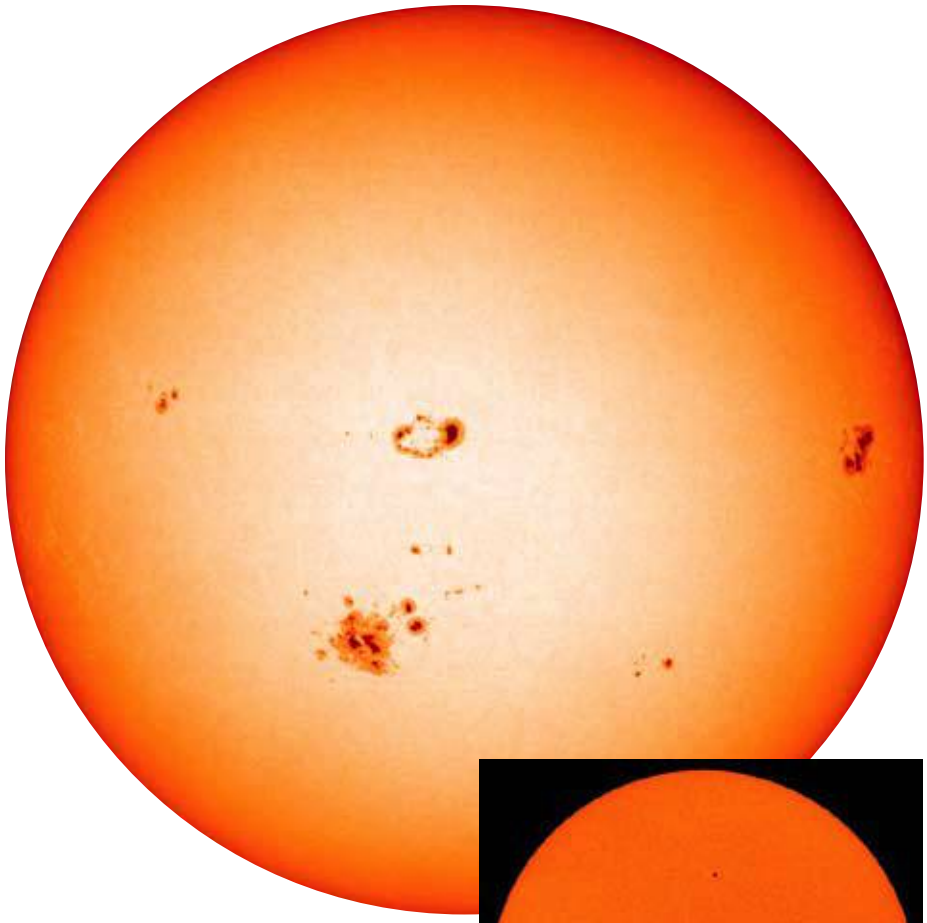
During the past 100 years alone, observers have reported between 40,000 and 50,000 sunspots. These numbers wax and wane with a fairly steady 11-year period. Yet the Sun's latest sunspot cycle, solar cycle 24, began almost a year late. In June and July of 2009, some anemic sunspot activity finally kicked in after a 2008 in which more than 260 days had no visible sunspots.

"Most of 2008 and 2009 were as dead as a doornail," says astronomer Gary Chapman, director of California's San Fernando Observatory, who has been running solar observations since 1986. "A typical sunspot is 2 or 3 times the size of Earth. We're seeing one or two tiny ones a month, smaller than Earth. During a normal solar maximum, you would have dozens of sunspots on any given day."

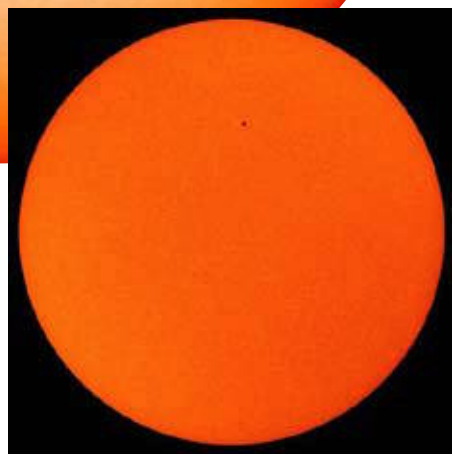
Records of sunspots date to the 4th century B.C. But in 1610, Galileo observed them in detail as they moved across the solar sphere. That happened some 30 years before the sunspots all but disappeared during the Maunder minimum, a 70-year period of diminished solar activity that lasted from 1645 to 1715.

Then, 2 centuries later, German amateur astronomer Heinrich Schwabe made an extraordinary discovery during a lengthy search for a planet inside Mercury's orbit. Schwabe noticed that his observations of sunspots seemed to show a peak about once a decade. For obscure historical reasons, astronomers slapped the label of "solar cycle 1" on an uneventful cycle that peaked in 1760.

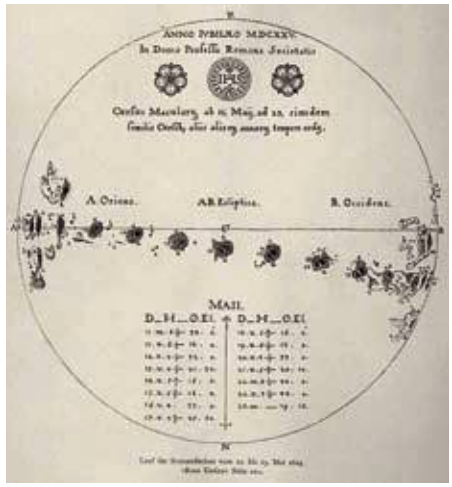
Since then, observers have watched 23 cycles come and go. "In March 2007, I predicted cycle 24 would be at least a year late," says UCLA solar physicist Roger Ulrich, who also began observing the Sun in 1986. "We've beat the 1905 extended solar minimum. The end of the Maunder minimum was the last time we had a cycle this long. But I think we're [now] coming into a period of rising solar activity."



▲ **Multiple sunspot groups** dot the Sun's surface October 28, 2003, when activity from solar cycle 23 remained quite high. SOHO (NASA and ESA)



▶ **A single small sunspot** mars an otherwise bland surface on the Sun February 2, 2010. The current solar cycle (number 24) got off to a later-than-normal start and has yet to ramp up significantly. SOHO (NASA and ESA)



Christoph Scheiner observed the Sun starting in 1611, about the same time as Galileo. The two scientists described dark spots moving across our star's surface. Linda Hall Library of Science, Engineering, and Technology

This anomalously long solar minimum raises the question of whether solar scientists actually understand the Sun's inner workings. "If you don't worry about the magnetic fields, we do," says Ulrich. "The magnetics is where the big puzzle is these days."

Solar scientists understand that solar magnetic fields start in the Sun's interior. Dynamic flows of plasma generate electrical currents that give rise to the Sun's active dynamo. This internal process gives birth to magnetic fields.

The Sun concentrates these fields, twisting and turning them in the process. Such distorted fields inhibit the ability of rising and falling gas cells to transport energy, a process scientists call convection. Where the magnetic fields break through the solar surface, or photosphere, temperatures can be as much as 2700° Fahrenheit (1500° Celsius) cooler than their surroundings. Such a region radiates less energy and looks darker — and we see a sunspot.

"According to the dynamo theory," says Ulrich, "the polar field generates the toroidal [circular] field, and the toroidal field generates the sunspots. The toroidal field is like a big rubber band wrapped up inside the Sun. It has kinks that pop up as sunspot pairs."

But that's not all that's happening just beneath the Sun's surface. East-west jet streams, known as torsional oscillations, slowly migrate from the Sun's middle latitudes to the equator and its poles.

Normally, their migrations take place over a 17-year period. But in 2009, solar physicists Rachel Howe and Frank Hill at the National Solar Observatory (NSO) in Tucson, Arizona, found that the zonal flow migration of the most recent cycle had slowed. "This jet stream is moving down toward the equator at a slower rate than the previous solar cycle," says Hill, "and the extra length of time it's taking is equivalent to the extended solar minimum. We conclude that they're related."

A new Maunder minimum?

Whether this jet stream is causing the extended solar minimum remains open to debate. Even so, stellar astronomer Mark Giampapa, deputy director of NSO, is one of the first solar researchers who thinks we may be entering a long-period, Maunder-type minimum, or a so-called grand solar minimum.

"My gut feeling is that we're heading into the next Maunder minimum," says Giampapa. "Our observational sunspot data archive since the 1980s points to a long-term trend of decreasing mean [average] magnetic field strengths in sunspots." Could these changes affect Earth in some way? After all, Giampapa notes that mean global temperatures have been declining from their maximum in 1998.

Hill doesn't think we're going into a Maunder minimum, although he suggests such long-term minima could originate from random dynamo action at the base of the Sun's convection zone.

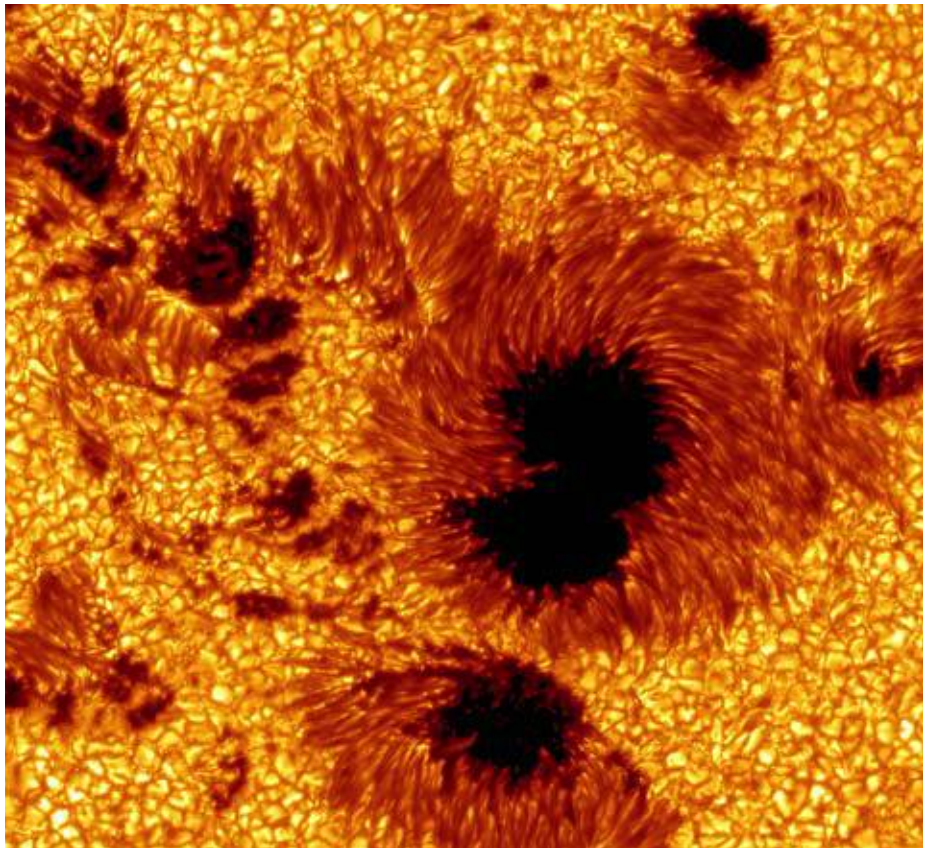
Even if we face an extended minimum, Hill doesn't think it would have a major effect on Earth. "I would guess a grand minimum would change global temperatures by a degree at the most," he says. But some solar researchers believe

Earth's own climate mechanisms could amplify any temperature changes in ways that solar physicists and climatologists still don't completely understand.

Steve Tobias, an applied mathematician at the University of Leeds in the United Kingdom, says "differential rotation" — the fact that the solar atmosphere rotates at different speeds at different latitudes and depths — generates the toroidal field that leads to the formation of sunspots. Changes in differential rotation could, in turn, weaken the solar dynamo. This could instigate an interval where the formation of active regions simply switches off, says Tobias. This also might modify the solar dynamo and cause the Sun to go through a Maunder-type minimum.

Looking to the stars

No matter what causes such events, Giampapa says he sees tentative evidence for Maunder-type cycles in some of the solar analogs he's observed. Giampapa and his Italian colleagues studied the open star cluster M67, located some 2,700 light-years from Earth in the constellation Cancer. If scientists confirm this trend, he says, it would indicate that



A sunspot group may comprise dozens of individual spots. Each spot typically contains a dark central region called the umbra, which is up to 2700° F (1500° C) cooler than the surrounding photosphere, and a lighter outer region called the penumbra. Royal Swedish Academy of Sciences

Europe suffers a deep freeze

Students of art history will readily identify a string of late-Renaissance Netherlandish paintings that depict what look like unusually harsh winters. From 1500 to 1850, a Little Ice Age engulfed much of the world, but its effects proved particularly strong in Northern Europe. Cool summers and colder-than-average winters were the norm. The unusually cold winters allowed "frost fairs" to be held on London's frozen River Thames as late as 1814.

In addition to the 70-year Maunder minimum from 1645 to 1715, two other solar minima affected Northern Europe during this epoch: the Spörer minimum from approximately 1415 to 1510 and the Dalton minimum from about 1795 to 1820.

Some researchers think volcanic ash might have triggered the Little Ice Age, and then the Maunder minimum amplified the effect. That's a view that Gary Chapman, a solar physicist and director of California's San Fernando Observatory, sees as plausible. "The Little Ice Age actually began before the Maunder minimum and continued into the Maunder minimum," says Chapman. "Maybe the Little Ice Age was bigger than it should have been if the Sun [hadn't been] involved."

Contrary to some reports, this period of solar inactivity was well-documented at the time. Researchers at the Paris Observatory alone made some 8,000 observations between 1660 and 1719. And, in 1887, after constructing a table of sunspots recorded between 1672 and 1699, German astronomer Gustav Spörer reported that he found fewer than 50 spots.

It's hard not to speculate how a grand minimum might affect our present climate. But if solar activity cuts out like it did during the Maunder minimum, says Chapman, we may start seeing some cooling effect. However, scientists still debate the specific effects of such grand minima. Part of this debate hinges on lingering questions about how Earth's atmosphere amplifies such solar variabilities.

As a result, the National Solar Observatory's Frank Hill says, there's a disconnect between solar physicists and climatologists. "Both solar physicists and climatologists need to come together about the impact of solar activity on climate," says Hill. — *B. D.*

The Little Ice Age brought unusually cold weather to much of northern Europe from 1500 to 1850. In this 1565 painting by Pieter Bruegel, a crowd skates on a frozen river. The lack of sunspots during the Maunder minimum may have exacerbated this 350-year cold spell.

Hot gas traces the Sun's magnetic field lines as they arc above the solar surface. Essentially all solar activity arises from magnetic forces acting beneath, at, and above the surface. TRACE/NASA/GSFC

such grand minima occur in Sun-like stars only 10 to 15 percent of the time.

"There is no doubt that the Sun experienced many more Maunder-type minima during the past 10,000 years," says Jürg Beer, a physicist at Switzerland's Eawag Research Institute. His team used the radioactive elements Beryllium-10 and Carbon-14 found in polar ice cores and tree rings to reconstruct solar history over the past 10,000 years. "The minima themselves do not show a clear periodicity. However, they seem to be clustered with a [spacing] of about 200 years."

But the Sun's magnetics, which drive both short-term solar magnetic cycles and perhaps even grand minima, present more of a puzzle. That's why observers and theorists alike need to compare the Sun with close solar analogs. So far, scientists have turned up only a couple dozen. The trick is not in finding stars that make a nice chemical match. Such stars are fairly common. But researchers also want to find stars with similar ages, masses, and magnetic cycles as the Sun.

One of Earth's nearest neighbors, Alpha Centauri A, is a true solar analog. It belongs to a triple star system that lies only 4.36 light-years away. With an estimated age of 6 billion years, however, it's about 1.5 billion years older than the Sun.

But Alpha Centauri A is just one star. Giampapa's team is studying 15 solar analogs in M67 with the European Southern Observatory's Very Large Telescope in Chile. M67 offers a unique laboratory to search for solar analogs because its stars' chemical compositions and ages (roughly 3.5 to 4.8 billion years old) are nearly the same as the Sun's. Giampapa says that after 6 years of observations, none of the stars his team has observed appears to have cycles that last less than 6 years.

"I'm seeing some brightness variability data that suggests the Sun might be more quiescent than most stars," says Giampapa. "But cycles in Sun-like stars in M67 could be quite similar to our Sun."

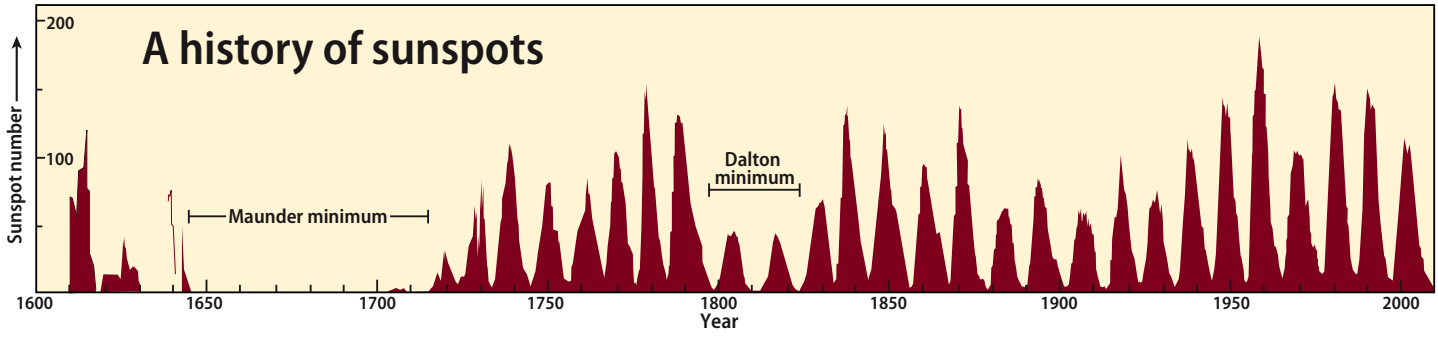
And a little quiescence might not be so bad. "We're near the end of our ropes here now," says astronomer Edward Guinan of Villanova University in Pennsylvania. That's because even though the Sun is only about halfway through its 10-billion-year hydrogen-burning lifetime, its increasing luminosity will make Earth uninhabitable much sooner — perhaps within the next 500 million years.

A better place for life?

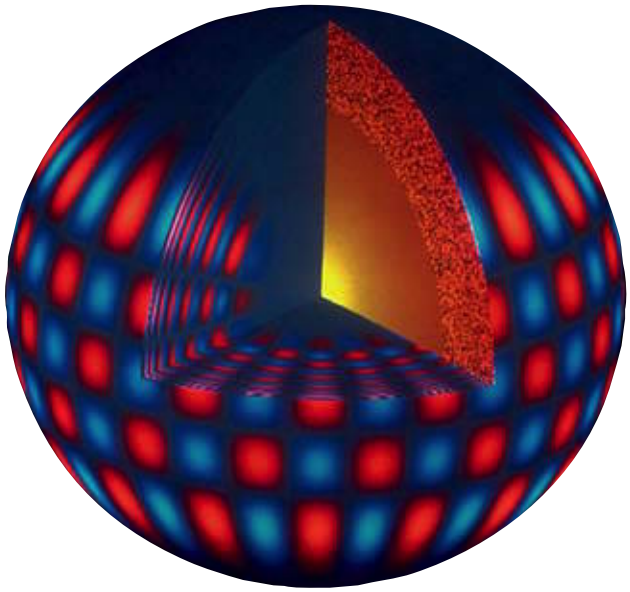
Because of its relatively short life, the Sun may not be the best candidate star for supporting planets with life. Guinan says that spectral type K stars may be better hosts. Such stars possess about 80 percent of the Sun's mass and burn cooler, so they fuse hydrogen stably for much longer. K stars have fixed habitable zones, regions where liquid water could exist on a planet's surface. Theoretically, intelligent life there could survive for 40 to 50 billion years.

Even cooler M stars make up some 75 percent of the galaxy's inhabitants. Although M stars live a long time, they glow dimly. Their habitable zones lie so close in that any planet orbiting within one would be tidally locked, with one side continuously facing the star and the other in constant darkness.

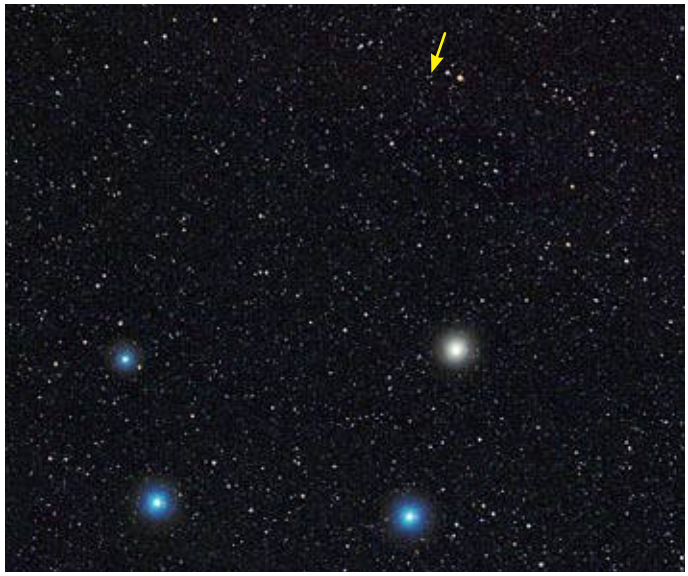
K and M stars have a further liability. Both types have more efficient dynamos than the Sun, so they produce more magnetic energy. Strong magnetic fields pose more danger than no magnetic fields, says Ulrich. He notes that the largest recorded eruption of charged particles from the Sun, a so-called coronal mass ejection, came during the 1859 solar superstorm. "The aurorae were so bright that people camping in Colorado awoke and decided



Typical solar cycles last about 11 years, but the strength of each cycle varies considerably. This illustration plots the yearly average sunspot numbers since 1610, when detailed observations began. During the Maunder minimum from 1645 to 1715, virtually no spots appeared. *Astronomy*: Roen Kelly



Helioseismology reveals the Sun's structure and dynamics by measuring sound waves generated in the interior. This computer representation shows rising gas in blue and sinking gas in red. NSO/AURA/NSF



This obscure star in Draco, HIP 56948, is the closest thing to a solar twin astronomers have discovered. The 9th-magnitude star lies just north of the Big Dipper's bowl. Bill and Sally Fetcher

it was dawn," says Ulrich. "Sparks flew out of all the telegraph instruments."

Such extraordinary events demonstrate how volatile our Sun can be. It also gives pause to wonder: Does the Sun's evolution and its often tumultuous solar cycles qualify it as normal?

To answer this question, astronomers need to probe the interiors of the Sun and other stars. The science of helioseismology studies the Sun's interior structure and dynamics by measuring sound waves emanating from our star. The best observations so far have come from the Global Oscillation Network Group (GONG).

An asteroseismological version of GONG — the Stellar Oscillations Network Group (SONG) — plans to study solar-like oscillations in nearby bright stars. This Danish-led international effort will link eight new telescopes spread over five continents, including the U.S. mainland and Hawaii.

Open star cluster M67 holds at least 15 close solar analogs — stars with similar masses, ages, and compositions as the Sun. Observations so far show that none of these analogs has a stellar cycle shorter than 6 years. Anthony Ayiomamitis

The network will offer full-sky 24-hour observational coverage. SONG researchers hope the first prototype, located in the Canary Islands, will see first light by early 2011. Giampapa says SONG-like global networks are what scientists need to confirm whether these solar analogs are indeed operating on solar-type cycles and experience Maunder-type grand minima.

Find a solar twin

Meanwhile, astronomer Jorge Meléndez at Portugal's University of Porto leads an international collaboration looking for solar twins. "My group has already studied about 75 percent of stars similar to the Sun in the whole Hipparcos million-star catalog," says Meléndez. "Surprisingly, we see that the Sun is actually chemically different from most solar twins."

That's in part because our star is lacking in refractory elements — those that vaporize at high temperatures — says Meléndez. These missing elements probably formed dust, which then accreted into planetesimals and ultimately into the terrestrial planets: Mercury, Venus, Earth, and Mars. Meléndez notes that an estimated 15 percent of stars seem to have a chemical composition similar to the Sun's, raising the possibility that such stars also may possess terrestrial planets.

Thus far, the closest to a solar twin Meléndez's team has found is the obscure star HIP 56948. This 9th-magnitude object lies some 217 light-years from Earth in the constellation Draco.

But NASA's Kepler mission should create an asteroseismological shift in the search for solar twins. During a 4-year period, Kepler will observe 100,000 stars in a single 100-square-degree field. The spacecraft's instruments are sensitive enough to measure the passage of individual starspots across the disks of its stellar targets.

Travis Metcalfe, an astronomer at the High Altitude Observatory in Boulder, Colorado, predicts that over Kepler's lifetime, the spacecraft will find at least 100 solar analogs. However, he emphasizes that the key to understanding the Sun in detail is the broader study of other stars. "There's always the danger that if we study this one object in great detail, we're just going to fine-tune our model to fit that one Sun," says Metcalfe. "But that same model has to work for other stars."

At the end of the Kepler mission, if not before, researchers should be able to partially settle our age-old quandary over what constitutes solar normality. And in the process, astronomers might just find a solar twin orbited by its own family of habitable terrestrial siblings.

To learn more about the Sun's biggest blasts, visit www.Astronomy.com/toc.

Mysteries of the Mag

They produced the nearest supernova in 300 years, are connected by a giant stream of matter, and may collide with the Milky Way.

by Bill Andrews

The Milky Way has a bit of a problem with its neighbors. Two smaller galaxies, the Large Magellanic Cloud (LMC) and the Small Magellanic Cloud (SMC), have buzzed around us for eons, giving no clear indication of their intentions. They may end up colliding with our galaxy, or they may leave one day, never to return. The LMC alone also has been host to a variety of explosions, both real (the closest observed supernova in 300 years) and fictional (*Battlestar Galactica* skirmishes).

Despite these potentially off-putting characteristics, astronomers can't get enough of the Magellanic Clouds. After all, they're fascinating and beautiful objects, and they might even hold the keys to understanding the biggest mysteries in the universe.

The road to fame

The Magellanic Clouds, as one might expect, appear as illuminated clouds, like pieces of the Milky Way that wandered off in the sky — but only to observers in the Southern Hemisphere. They were surely known to the indigenous peoples of the South Seas, but their first recorded mention dates back to A.D. 964, in Persian astronomer Abd Al-Rahman Al Sufi's *Book of Fixed Stars*. Al Sufi, later known in Europe as Azophi, identified the LMC as Al Bakr, or "The White Ox," and noted that it is visible only from southern latitudes.

The Clouds' first recorded European mention occurred more than 500 years later, in a letter from explorer and cartographer Amerigo Vespucci. During his third voyage from 1503 to 1504, he wrote of "three Canopes, two bright and one obscure" in the southern skies, with the former referring to the Magellanic Clouds and the latter likely referring to the Coalsack Dark Nebula.

The big break for the Clouds came just decades later, after Ferdinand Magellan's circumnavigation of Earth from 1519 to 1522. Of the initial crew of 237 men, only 18 finished the journey and returned to Spain. One of the lucky few was Venetian scholar Antonio Pigafetta. His description of the Clouds as dim clusters of stars became widely known to Western astronomers, and it's because of his reports that the galaxies are now named for Magellan.

The Clouds' final push toward superstar status had to wait another four centuries. In 1987, the region near the Tarantula Nebula in the LMC was host to a fantastic sight: the closest

Bill Andrews *is an assistant editor of* Astronomy. *He's read about the (fictional) planet Tralfamadore, located in the Small Magellanic Cloud, for more than half his life.*

ellanic Clouds

The Tarantula Nebula, a prominent feature of the Large Magellanic Cloud, is considered the most active star-forming region in the Local Group of galaxies. Both Magellanic Clouds are full of celestial treasures like this one. John P. Gleason

A supernova near the LMC's Tarantula Nebula burned brightly in 1987, giving Southern Hemisphere observers the closest look at these stellar explosions since 1604. This Hubble photo depicts the supernova remnant centered in rings of cast-off material, in the midst of diffuse clouds of gas. NASA/HST

observed supernova, or stellar explosion, since 1604 (before the invention of the telescope).

"The most spectacular thing that a human ever could see would be an explosion of a star," says Jürgen Knödlseder of the Center for the Study of Radiation in Space in Toulouse, France. "I think that garnered [a lot of interest] for normal people, just to witness the fact that a star exploded, by naked eye, because it's such a rare phenomenon."

Even more unusual than a solar eclipse, the dazzling new "star" with an apparent magnitude of 3 brought an unprecedented level of attention to the Magellanic Clouds. As Knödlseder says, "It was famous all over."

Galactic profiles

Of course, for astronomers, whose job it is to look at and understand the heavens, the Magellanic Clouds had been well-known for some time. The Tarantula Nebula in particular has long been considered the most active star-forming region in the Local Group of galaxies. It's just one of the fantastic objects and phenomena, from globular clusters to planetary nebulae to an environment with unusually low metallicity (meaning a place with fewer elements heavier than helium), that make the LMC a focus of galactic study.

Despite being an irregular galaxy (one with no obvious shape, like a spiral or elliptical), the LMC has a prominent central bar and a spiral arm. The central bar is so warped that its ends are nearer to the Milky Way than its middle. The galaxy lies approximately 160,000 light-years from Earth and is about one-tenth as large as the Milky Way.

About 22° away from the LMC in the sky (75,000 light-years away in reality) and 200,000 light-years distant from Earth, the SMC is also an irregular galaxy low in metals, but

This combined radio/optical image outlines the interaction of the Magellanic Clouds with each other and the Milky Way (shown horizontally centered). Some theories predict the Clouds will ultimately end up in our galaxy, "cannibalized" by its larger gravity. The blue and white represents the Milky Way and Magellanic Clouds, red is the hydrogen gas of the Magellanic Stream and the disks of the Magellanic Clouds, and brown is dust clouding the Milky Way. Nidever, et al./NRAO/AUI/NSF and Mellinger/Leiden-Argentine-Bonn Survey/Parkes Observatory/Westerbork Observatory/Arecibo Observatory

about 10 times smaller than its companion. The two seem to be embedded in an "envelope" of hydrogen gas of much lower density than either Cloud called the Magellanic Bridge.

Their low metal contents and higher gas concentrations mean the Magellanic Clouds are "much closer to what galaxies in the early universe used to have," says Snezana Stanimirovic, assistant professor of astronomy at the University of Wisconsin-Madison. "By studying the physical processes in the Magellanic Clouds … we can learn about galaxy evolution and how it depends on dust, gas, and metal content."

For example, the Magellanic Clouds helped explain the unknown origin of cosmic rays, particles that bombard Earth from anywhere beyond its atmosphere. "For a long time," Knödlseder says, "the question was: Are the cosmic rays generated in our own galaxy, or are they just a kind of bath [spread] throughout the universe?"

Either theory could explain the cosmic rays we see almost uniformly on Earth, but if the second theory was right and they blanketed the entire universe, astronomers should be able to detect cosmic ray interactions in other galaxies. When they didn't see any interactions in the SMC, astronomers could conclude that the source of cosmic rays must lay within individual galaxies, according to Knödlseder. "It's not a blanket, universal phenomenon."

Spying on the neighbors

Despite their unusual makeup, the Magellanic Clouds serve as extraordinarily valuable tools for understanding the rest of the universe. "Many of the processes are basically the same" among the Clouds and other galaxies, says Knödlseder, "so they provide a much deeper view of what's going on in other galaxies, and how their different components interact."

Further, due to our position in our own galaxy, it's hard to know exactly what we're seeing when we look at Milky Way phenomena, explains Knödlseder. For example, is this supernova remnant interacting with that molecular cloud, or is one just in front of the other? Studying the Magellanic Clouds, Knödlseder says, is a "little bit like if you could fly out of our own galaxy and look at it from the top."

And it's not just the nice view that makes the Magellanic Clouds a useful target. "The Magellanic Clouds are basically our neighbors," says Annapurni Subramaniam of the Indian Institute of Astrophysics. Scientists study them for the same reason they study the Sun: They're so close, they can give us more details than something farther away. "And probably we are assuming a lot of things for other galaxies, so we

Magellanic Timeline

Prehistory — The Magellanic Clouds are easily visible in the Southern Hemisphere to the naked eye.

A.D. 964 — Persian astronomer Abd Al-Rahman Al Sufi makes the first recorded mention of the Large Magellanic Cloud, calling it Al Bakr, or "The White Ox."

1503 — Explorer and mapmaker Amerigo Vespucci provides the first European recorded mention of the Clouds in a letter from his third voyage.

1522 — Venetian scholar Antonio Pigafetta's description of the Clouds, seen during his time on Magellan's round-the-world voyage, circulate throughout Western countries.

1970s — Astronomers discover the Magellanic Stream and realize it's connected to the Magellanic Clouds.

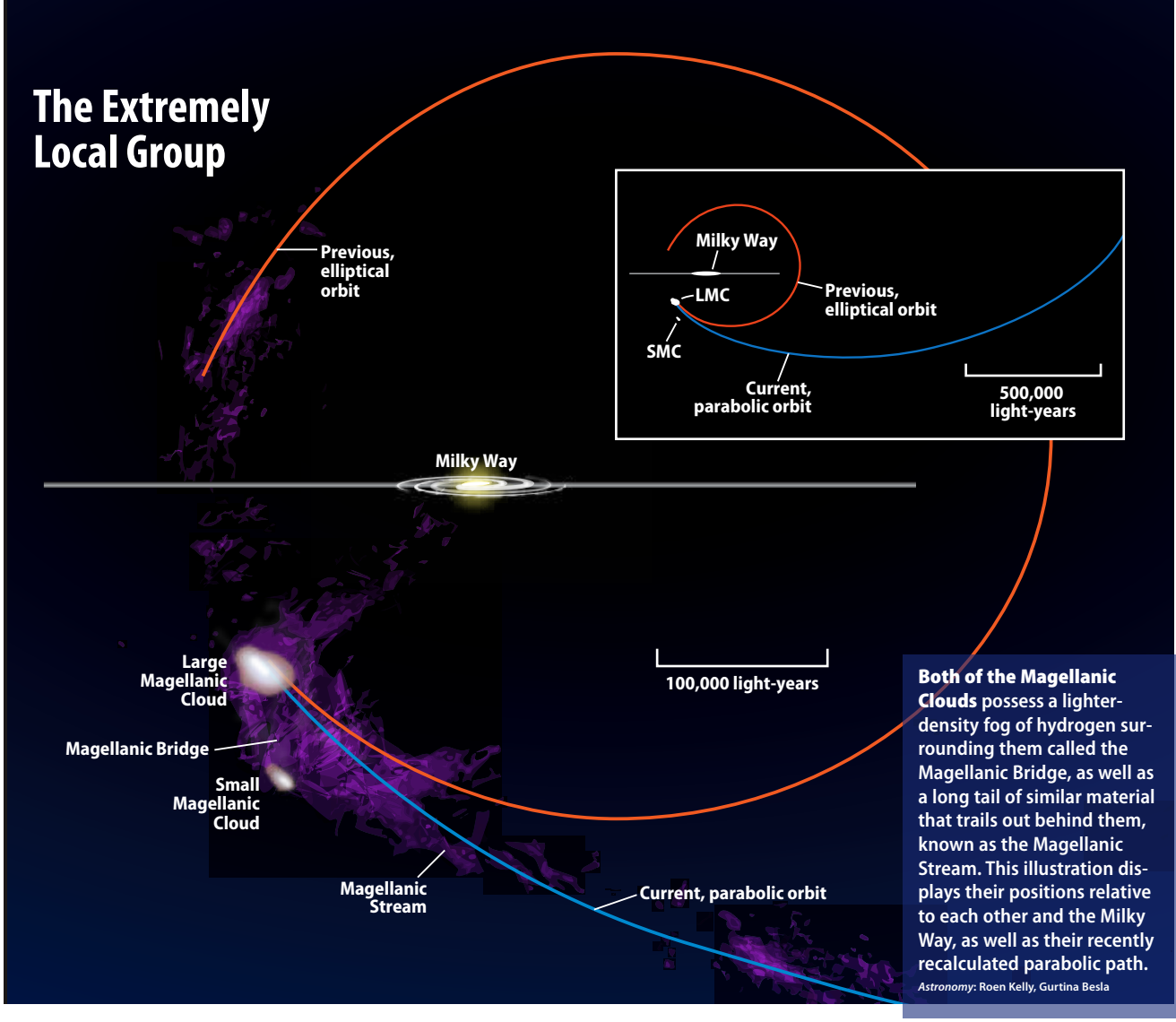
1987 — In February, the closest supernova in almost 300 years appears in southern skies near the LMC's Tarantula Nebula.

2007 — New Hubble observations show that the Magellanic Clouds travel much faster than previously thought, likely implying a parabolic path around the Milky Way instead of an elliptical orbit.

February 2008 — Astronomers discover a giant strand of the Magellanic Stream poking through the Milky Way's disk, possibly implying that our galaxy is "cannibalizing" its two smaller companions.

January 2010 — The Magellanic Stream turns out to be much longer and older than previously thought.

Book: University of California, Irvine; Magellan: Naval Museum of Madrid; Supernova 1987A: NASA/CXC/PSU/S.Park & D.Burrows/STScI/CfA/P. Challis; Clusters: ESA & NASA/Davide de Martin and Edward W. Olszewski (University of Arizona, USA)



Both of the Magellanic Clouds possess a lighter-density fog of hydrogen surrounding them called the Magellanic Bridge, as well as a long tail of similar material that trails out behind them, known as the Magellanic Stream. This illustration displays their positions relative to each other and the Milky Way, as well as their recently recalculated parabolic path. *Astronomy:* Roen Kelly, Gurtina Besla

must check it out with the nearby ones first," says Subramaniam. That's particularly prudent advice, given how many times the Magellanic Clouds have proven scientists wrong.

Magellanic missteps

Supernova 1987A surprised everyone with its unexpectedly close and glittering show, but it particularly surprised astronomers. The star that exploded into SN 1987A turned out to have been a blue supergiant, a class then considered unable to "go" supernova. While it's still not completely understood, astronomers now suspect the object was once a binary system whose stars had merged, producing the blue supergiant thousands of years later.

SN 1987A was a core-collapse supernova, which should have left behind a neutron star. Despite more than 20 years of searching, however, no evidence of a neutron star has turned up. Astronomers have proposed several theories as to why not, but it's still a mystery.

Another, more fundamental misunderstanding involves the galaxies' very natures. "For a long, long time, scientists thought that the Magellanic Clouds were gravitationally bound to the Milky Way," says Stanimirovic. They believed the Clouds moved in an elliptical orbit, periodically nearing and departing the Milky Way over billions of years.

Then, in 2007, Harvard astronomers used data from the Hubble Space Telescope to determine that the Magellanic Clouds actually moved much faster than previously thought. "When they tried to use new data and go back into [original calculations], they realized that it was getting really, really hard to reproduce this bound, elliptical orbit," says Stanimirovic. So instead of being regulars in the Milky Way's neighborhood, it turns out the Magellanic Clouds are more likely on a parabolic orbit that takes them near the Milky Way just once.

"Those were really shaking results in the community," Stanimirovic says, "because for decades astronomers have been working with the assumption that the Clouds are orbiting around the Milky Way." Now, everything is different. "This destroys decades of numerical modeling of interactions between the Magellanic Clouds and the Milky Way Galaxy."

For example, astronomers had long theorized that the Milky Way's warped disk resulted from the gravitational pull of the Clouds' occasional passes. But, if they're really on a one-way trip by the Milky Way, astronomers will have to come up with another explanation. Another new puzzle involves trying to make sense of the intermittent star-forming activity in the Magellanic Clouds without counting on the occasional gravitational effects of the Milky Way present in an elliptical orbit.

Finally, a parabolic orbit likely means the Clouds would just pass by and keep on going into space. "They would never get close to us again," says Stanimirovic. "Their fate would be totally unknown." Well, maybe.

Now streaming

For more than 30 years, astronomers have known about a huge tail that stretches away from the Magellanic Clouds, spanning more than 100° in the sky. Consisting mainly of hydrogen, it's dubbed the Magellanic Stream and has been the subject of much recent scientific revision. And in February 2008, Australia's Commonwealth Scientific and Industrial Research Organisation found that a pointy "finger" of gas opposite the Stream appears to puncture the Milky Way's disk about 70,000 light-years from Earth, near the Southern Cross from our perspective. The researchers expect the rest of the Magellanic Clouds to sort of "fall" into the Milky Way, eventually leading to a galactic merger between it and the Magellanic Clouds powered mostly by gravity. Of course, this isn't a certainty yet either.

In January, David Nidever of the University of Virginia found that the Magellanic Stream is more than 40 percent longer than previously thought, and thus almost certainly older. The newer estimate makes the Stream around 2.5 billion years old, placing its birth at about the same time as when scientists suspect the two Magellanic Clouds passed near each other. The brush likely caused star formation and supernova explosions turbulent enough to blow out the first tendrils of the Stream. This discovery is welcome news because it provides a new, plausible explanation for the Stream that doesn't involve orbiting the Milky Way.

The Magellanic Clouds, visible in the Southern Hemisphere, appear as glowing clouds in the night sky. The Large Magellanic Cloud, seen here, lies about 160,000 light-years away and is classified as an irregular galaxy, despite its central bar and spiral arm. NASA

The Small Magellanic Cloud, about 200,000 light-years distant, is an irregular galaxy about 10 times smaller than the LMC and 100 times smaller than the Milky Way. NASA/ESA/HST

To the future

Naturally, we haven't seen the last of the Magellanic Clouds, our galactic neighbors as Subramaniam put it. "You can live without talking to them or making any contact with them," she says. "But talking to a neighbor probably can give you a little more info, or new insight, or new depths. Understanding the Magellanic Clouds is important from that point of view: It gives new direction to understanding."

And a number of facilities will lead the charge. The Atacama Large Millimeter/submillimeter Array will provide a high-resolution view of many of the molecular species residing in the Clouds starting in 2012, helping us better understand star formation in such galaxies. The European Space Agency's Herschel Space Observatory is mapping the distribution of cold dust across the Clouds, teaching us about this virtually unknown component of the interstellar medium within galaxies. And the Australian Square Kilometer Array Pathfinder will map the Magellanic system with 10 times higher resolution than ever before in 2013, providing some answers about its composition, but, most likely, also new questions.

"The future is bright for the Magellanic Clouds," says Stanimirovic, and thus far so is galactic research in general. As Magellan himself proved (albeit posthumously), everything is connected — there are no edges to our understanding.

Whether looming large after 1987's supernova, being all but forgotten for centuries, or rewriting the rules of our galactic neighborhood, the Magellanic Clouds have plotted a complex course with our imagination.

"The Magellanic Clouds are an eye-opener," says Subramaniam. "It's good to explore and find out what things are possible."

Surely Ferdinand would agree.

Read Senior Editor Richard Talcott's story, "The First Days of SN 1987A" online at www.Astronomy.com/toc.

The Sky this Month

Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

June 2010

Jupiter meets Uranus at dawn

June 21 marks the first day of summer in the Northern Hemisphere. This places the Sun at its highest point in the sky at local noon. Conversely, the ecliptic — the apparent path of the Sun and planets across the sky — hangs lowest in the sky at local midnight.

This is bad news for those observing Jupiter, Uranus, and Neptune, which peak late at night and early in the morning. But it has little effect on evening views of Venus, Mars, and Saturn.

As twilight descends June 1, Venus, Mars, and Saturn lie along a nearly straight line that spans a bit more than 70°. Thanks largely to Venus' rapid motion, this angle shrinks to less than 40° by June 30.

Of the threesome, **Venus** appears closest to the horizon. It begins the month near the center of the constellation Gemini the Twins. But the planet is on a mission to escape the Sun's clutches. It moves quickly into eastern Gemini, where it forms a straight line with that constellation's two brightest stars, Castor and Pollux, June 11.

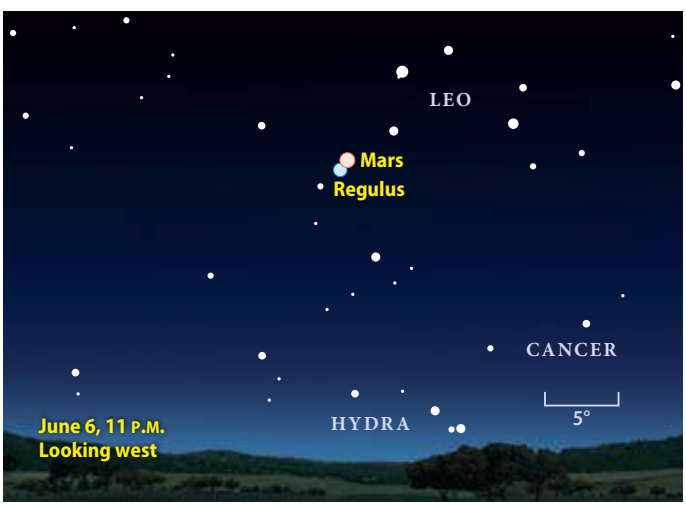
The next night, Venus exits the Twins' abode and enters Cancer the Crab. The crescent Moon joins Venus June 14, when our only natural satellite stands 4° below the planet. On the following night, the Moon lies 12° to Venus' left. As the planet continues its eastward march, it passes just north of the Beehive star cluster (M44) June 19 and 20. Wait for the twilight glow to diminish, then point your binoculars at the pair. The planet's brilliant, steady glow will contrast nicely with the faint, twinkling stars of the famous cluster.

By the time June closes, Venus has crossed into Leo the Lion. It then gleams at magnitude –4.1, two-tenths of a magnitude brighter than when it started the month. The planet shines so bright, you won't mistake it for any other celestial object. An airplane's landing lights might briefly mimic its appearance, but a few minutes is all it takes to see a plane's motion.

Be sure to check out Venus through your telescope. The best time to look is during twilight, when the dazzling orb won't overpower the view. During June, the planet's

— *Continued on page 41*

The Moon dips into Earth's shadow before dawn June 26. At the peak of this partial lunar eclipse, slightly more than half of the Full Moon will lie in darkness. Anthony Ayiomamitis



Red and blue contrast in the evening sky during early June when Mars passes just north of the 1st-magnitude star Regulus. The Red Planet lies closest to Regulus June 6. *Astronomy:* Roen Kelly

36 Earth eclipses the Moon
36 Mars and Regulus in color
41 Meteor watch
41 Rising Moon
42 When to view the planets
42 Titan joins Rhea
42 Comet search
43 Locating asteroids
43 Jupiter points to Uranus

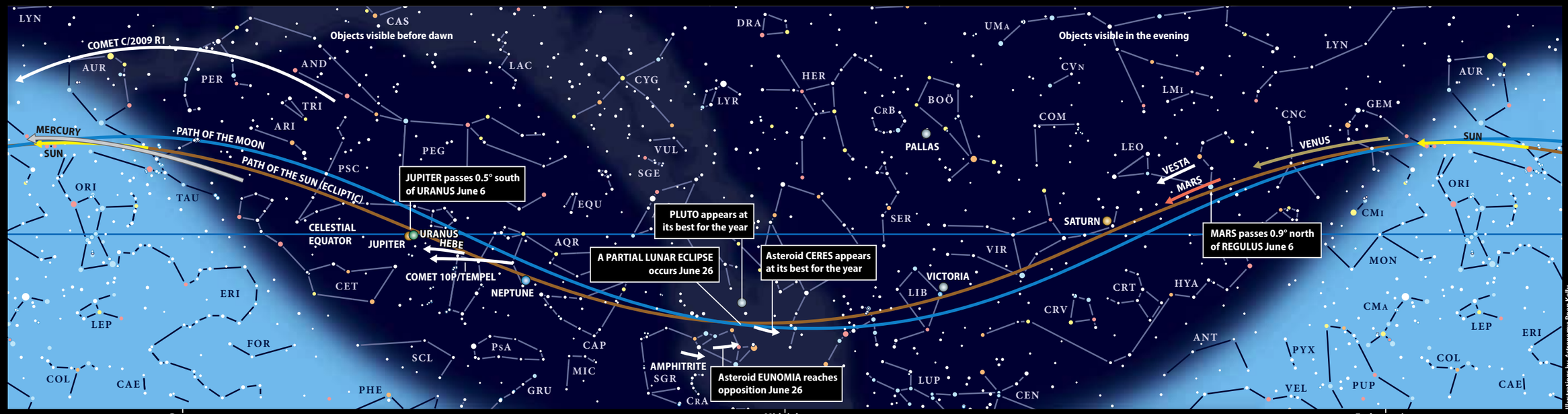
Visible to the naked eye
Visible with binoculars
Visible with a telescope

Planets in June 2010

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine

Path of the planets



Illustrations by *Astronomy*: Roen Kelly

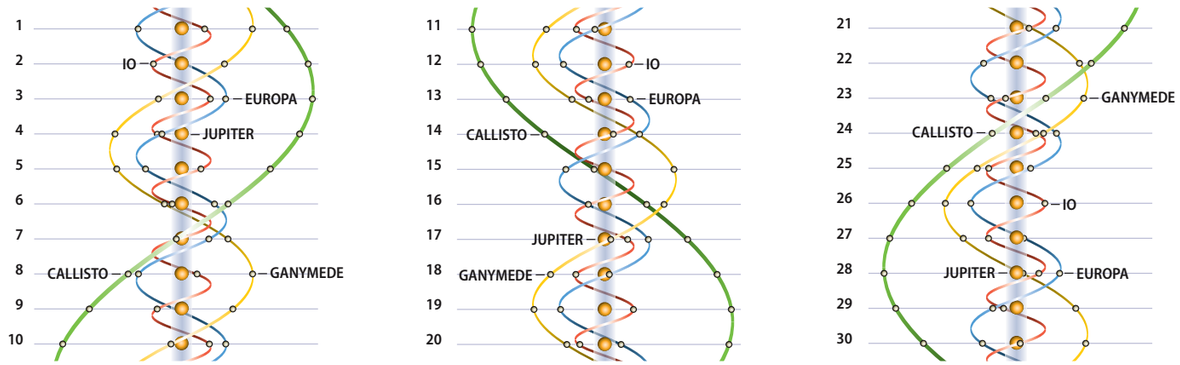
MOON PHASES

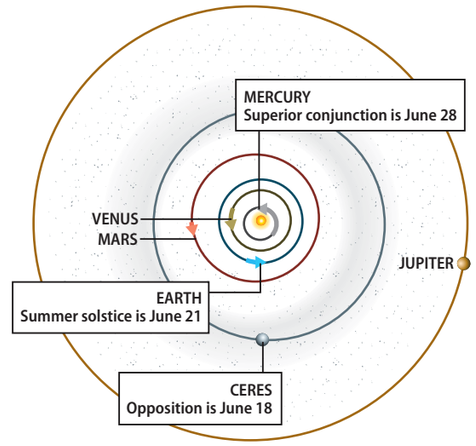
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown at 0h Universal Time.

PLANETS	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	June 1	June 15	June 15	June 15	June 15	June 15	June 15	June 15	June 15
Magnitude	0.1	–4.0	1.2	7.1	–2.4	1.1	5.9	7.9	14.0
Angular size	7.3"	14.0"	5.6"	0.7"	39.5"	17.7"	3.5"	2.3"	0.1"
Illumination	50%	76%	91%	100%	99%	100%	100%	100%	100%
Distance (AU) from Earth	0.924	1.192	1.672	1.825	4.996	9.396	20.186	29.574	30.854
Distance (AU) from Sun	0.416	0.720	1.638	2.839	4.971	9.525	20.094	30.020	31.849
Right ascension (2000.0)	2h58.9m	8h13.1m	10h25.1m	17h52.4m	0h05.4m	11h56.0m	0h02.2m	22h03.3m	18h17.7m
Declination (2000.0)	13°41'	21°59'	11°08'	–25°14'	–0°44'	3°01'	–0°35'	–12°26'	–18°14'

Jupiter's moons

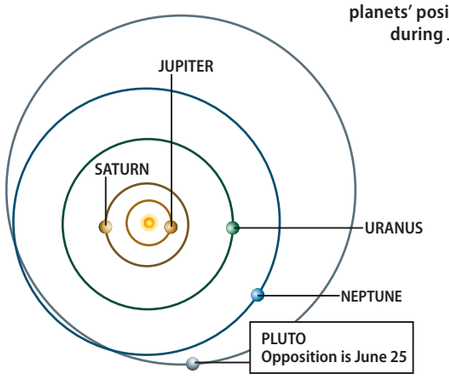
Dots display positions of Galilean satellites at 4 A.M. EDT on the date shown.
South is at the top to match the view through a telescope.





The planets in their orbits

Arrows and dots show planets' positions during June.



StarDome

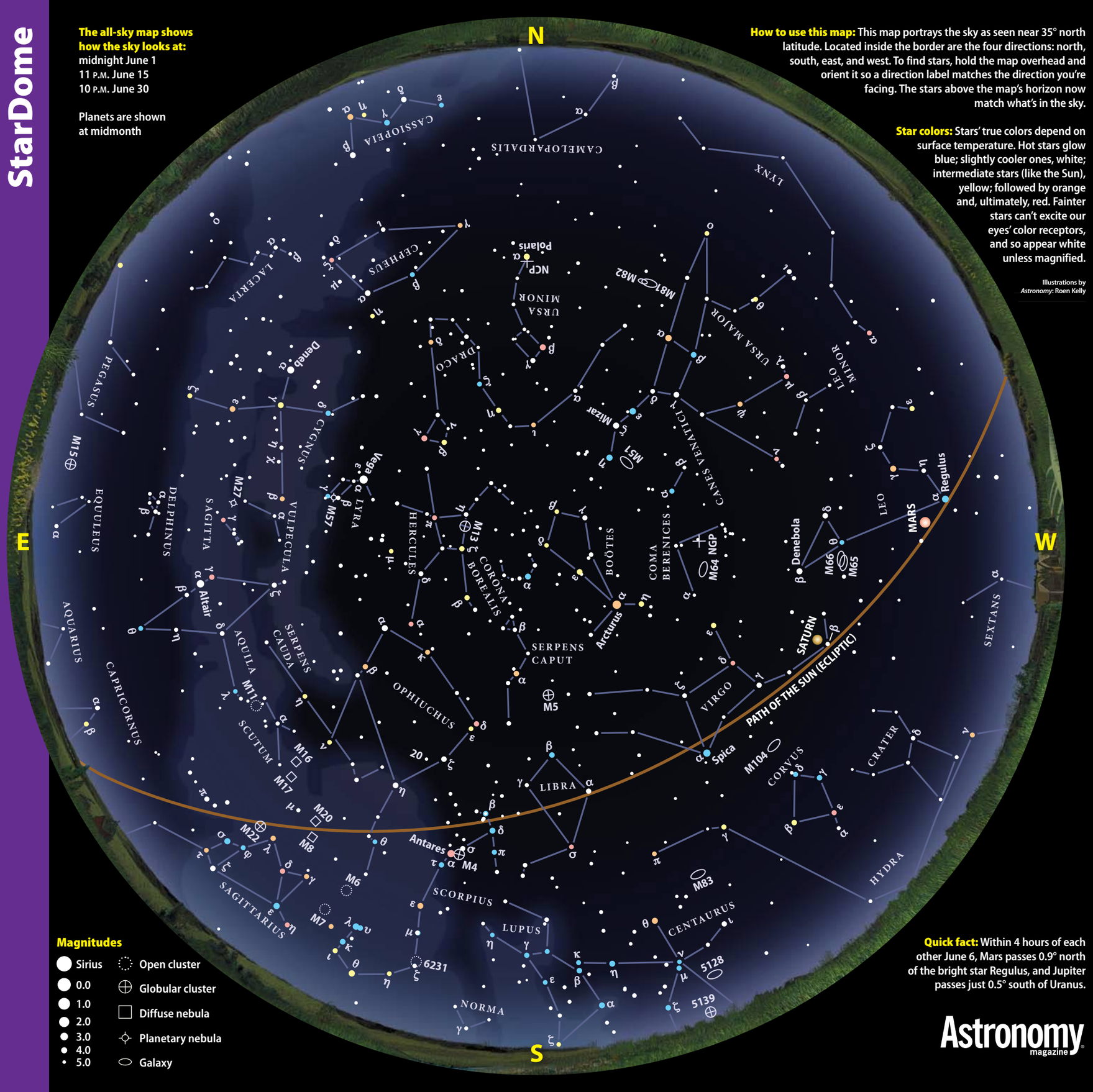
The all-sky map shows how the sky looks at:
midnight June 1
11 P.M. June 15
10 P.M. June 30

Planets are shown at midmonth

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Roen Kelly



Magnitudes

Sirius	Open cluster
0.0	Globular cluster
1.0	Diffuse nebula
2.0	Planetary nebula
3.0	Galaxy
4.0	
5.0	

Quick fact: Within 4 hours of each other June 6, Mars passes 0.9° north of the bright star Regulus, and Jupiter passes just 0.5° south of Uranus.

Astronomy magazine

June 2010

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

Calendar of events

3 The Moon is at apogee (251,199 miles from Earth), 12:50 P.M. EDT

The Moon passes 5° north of Neptune, 2 P.M. EDT

4 Last Quarter Moon occurs at 6:13 P.M. EDT

6 The Moon passes 7° north of Jupiter, 7 A.M. EDT

The Moon passes 6° north of Uranus, 7 A.M. EDT

Mars passes 0.9° north of Regulus, 11 A.M. EDT

Jupiter passes 0.5° south of Uranus, 3 P.M. EDT

9 Venus passes 5° south of Pollux, 6 A.M. EDT

10 The Moon passes 5° north of Mercury, 11 P.M. EDT

12 New Moon occurs at 7:15 A.M. EDT

15 The Moon passes 4° south of Venus, 3 A.M. EDT

The Moon is at perigee (227,380 miles from Earth), 10:59 A.M. EDT

Mercury passes 5° north of Aldebaran, 10 P.M. EDT

17 The Moon passes 6° south of Mars, 3 P.M. EDT

18 Asteroid Ceres is at opposition, 6 P.M. EDT

19 First Quarter Moon occurs at 12:29 A.M. EDT

The Moon passes 8° south of Saturn, 7 A.M. EDT

21 Summer solstice occurs at 7:28 A.M. EDT

25 The Moon passes 1.0° north of asteroid Ceres, 3 P.M. EDT

Pluto is at opposition, 3 P.M. EDT

26 Full Moon occurs at 7:30 A.M. EDT; partial lunar eclipse

Asteroid Eunomia is at opposition, 10 P.M. EDT

Special observing date

26 Today's partial lunar eclipse is the first one visible from the contiguous United States since February 2008.

28 Mercury is in superior conjunction, 8 A.M. EDT

30 The Moon passes 5° north of Neptune, 9 P.M. EDT

See tonight's sky in Astronomy.com's STARDOME

— *Continued from page 36*

angular diameter increases from 13" to 15" while its phase diminishes from 81 percent to 71 percent lit. Both changes indicate that Venus is moving closer to Earth. By June 30, it lies just 100 million miles away — a stone's throw on the solar system's scale.

Shift your gaze to Venus' upper left, and your eyes will land on **Mars**. The ruddy planet makes a fine pair with blue-white Regulus, Leo's brightest star, which lies at the base of the constellation's distinctive Sickle asterism. The color contrast between Mars and Regulus shows up best around June 6, when the planet passes 1° (two Moon-widths) north of the star. But the two remain near each other throughout the first half of the month.

At their closest approach, Mars shines at magnitude 1.2, just a hair brighter than Regulus. The colors appear most vivid through binoculars. Their added light-gathering capability better stimulates your eyes' color receptors.

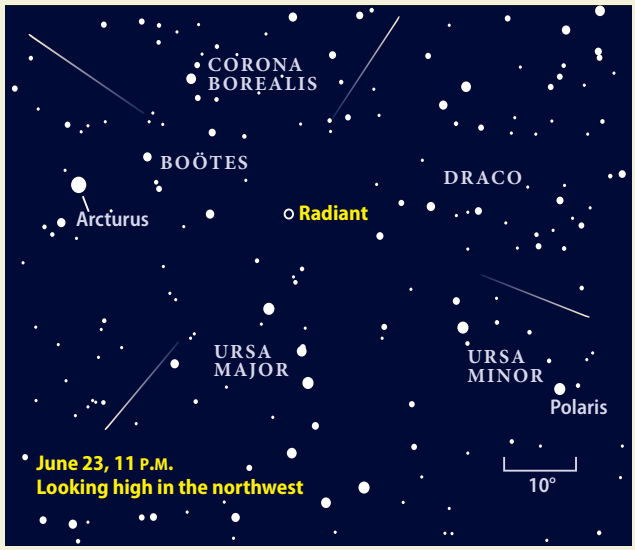
Unfortunately, the time for viewing Mars through a telescope has passed. The Red Planet lies about 155 million miles from Earth in mid-June. Coupled with the planet's small physical size, this large distance renders Mars tiny in the eyepiece, just 6" across. Only the largest backyard telescopes will show surface features with any clarity.

The Moon forms a nice triangle with Mars and Regulus June 16. The slender crescent then stands 5° from Regulus and 9° from Mars. The following night, the Moon lies 9° south of Mars. The planet's eastward trek against the backdrop of Leo continues all month. As June ends, Mars lies 13° from Regulus and sets before midnight local daylight time.

Saturn stands high in the southwest at sunset. It lies in the western part of Virgo, 2° from the 4th-magnitude star Beta (β) Virginis. The 1.1-magnitude planet shines some 10 times brighter than the

Martin Ratcliffe *provides professional planetarium development for Sky-Skan Inc. in Nashua, New Hampshire. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*

Meteor watch



The Boötid meteor shower could put on a nice show June 23, although the meteors must contend with moonlight. *Astronomy*: Roen Kelly

Watch for a herd of meteors

Meteor showers can be fickle. Take the Boötid display, for example, which lay dormant from 1927 until 1998. The shower spawned up to 100 meteors per hour in 1998 and had another nice display in 2004. Because the Boötids parent comet, 7P/Pons-Winnecke, has a 6-year period, the shower could shine again in 2010.

The International Meteor Organization predicts a possible increase in activity this year from debris Pons-Winnecke laid down in the 19th century. The peak should occur the night of June 23/24, likely between 7 P.M. and midnight EDT, when a gibbous Moon interferes. Still, no one knows what kind of show the Boötids will put on, so watching that night could pay dividends.

The meteors appear to radiate from the constellation Boötes the Herdsman, which lies high in the sky throughout June evenings. Boötid meteors hit Earth's atmosphere at "just" 40,000 mph.

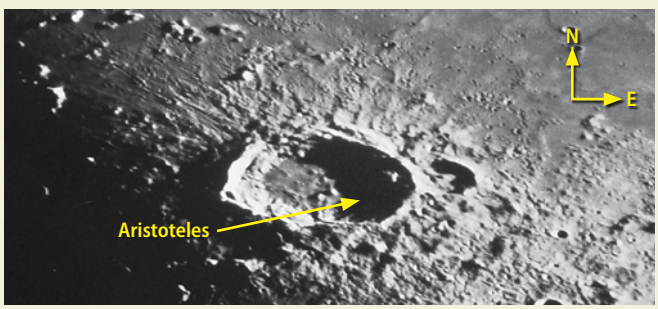
Rising Moon

Shadows play across a thinking man's crater

A couple of days before First Quarter Moon, our celestial companion shows a face divided in thirds. The southern third is a crowded, cratered mess. This quickly morphs into the slate-gray maria that dominate the equatorial regions. The smoothness of the Moon's northern third is punctuated by a handful of large, identifiable craters.

This month's target lies in the northern third and comes into view starting June 17. That evening, the crater Aristoteles appears as a bright-rimmed ellipse surrounding a black hole. One Earth day later, the crater's multiple central peaks catch the rising Sun. Significantly smaller craters tend to boast cleaner lines and simpler central peaks. But the massive amount of energy required to gouge out 54-mile-wide Aristoteles significantly altered its final shape. In moments of good seeing, you'll find lots of structure to view here.

The vast amount of soil excavated from the blast splattered back down in a large apron around Aristoteles. This created a seemingly uncountable number of secondary craters. You can see them flit in and out of view only near lunar sunrise or sunset. Just one Earth night later, the higher Sun erases these tiny shadows from view.



A massive impact created the 54-mile-wide crater Aristoteles in the Moon's northeastern quadrant. Look for myriad secondary craters during moments of good seeing. *Consolidated Lunar Atlas*/UA/LPL

As Full Moon approaches, pop in a filter to cut down the glare. The gentle arc of dark gray across the lunar north is Mare Frigoris. And Aristoteles has been transformed into an oval of light material paired with the smaller and more circular crater Eudoxus just to its south. You can't help but be impressed by the marked change.

When to view **the planets**

EVENING SKY	MIDNIGHT	MORNING SKY
Venus (west)	Mars (west)	Mercury (east)
Mars (west)	Saturn (west)	Jupiter (southeast)
Saturn (southwest)		Uranus (southeast)

star. You can watch Saturn track slowly eastward relative to Beta throughout the summer months. On June 18, you can find Saturn 8° above the First Quarter Moon.

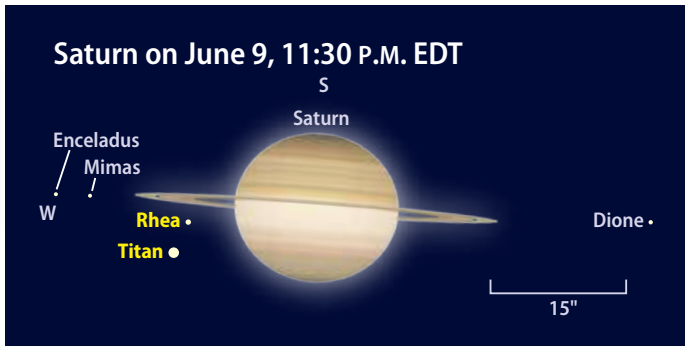
Saturn's distance from Earth continues to grow, so its apparent size shrinks. In mid-June, the planet measures 18" across its equator and about 10 percent less through the poles. The rings span 40".

In early June, the rings tilt 1.7° to our line of sight, a fraction more than their minimum for the year set in late May. They open marginally wider by June 30. During the next 2 months, however, the rings will double their early June tilt. When Saturn reappears in the morning sky in late October, the tilt will have widened to 8°.

Our nearly edge-on view of the rings provides good opportunities for viewing Saturn's moons near one another. Eighth-magnitude Titan and 10th-magnitude Rhea approach each other regularly. Their best conjunction this month for North American observers occurs June 9/10.

As soon as the sky grows dark, swing your scope to Saturn, and you'll find Titan and Rhea 4" apart and just north of the rings' western edge. As the evening progresses, the pair moves toward Saturn's limb. Saturn eventually occults Rhea, at 12:45 A.M. EDT (9:45 P.M. PDT). Two hours later, Saturn occults Titan (at 11:40 P.M. PDT). Observers west of the Rocky Mountains will have a clear view of this final event while those east of the Rockies will see it low in the western sky.

The outer moon Iapetus reaches its greatest elongation east of Saturn June 16. It then appears faintest, glowing dimly at 12th magnitude. It



Astronomy: Roen Kelly

Rhea slides past Titan near Saturn's western limb the evening of June 9. At closest approach, the two moons appear just 4" from each other.

appears about 5 times brighter at greatest western elongations, although the next one of those occurs 40 days later. The effect comes about because Iapetus has one bright and one dark hemisphere, and opposite sides face Earth when Iapetus appears farthest from Saturn.

The dwarf planet **Pluto** reaches opposition and best visibility June 25. It lurks in a region about 3° north of Mu (μ) Sagittarii. Pluto glows at magnitude 14.0, which makes it 1,000 times dimmer than the faintest stars visible to the naked eye. You'll need a detailed star chart to correctly identify it. To find the general region of sky, draw a line between M23 and M25, two bright open star clusters in northern Sagittarius. At opposition, Pluto lies less than 1° above that line's midpoint.

Neptune pokes above the eastern horizon not long after midnight. To see it well, however, you'll want to wait until about 3 A.M. local daylight time. By then, the distant planet has climbed nearly a third of the way up in the southeastern sky.

Neptune glows at magnitude 7.9 among the stars of Aquarius the Water-bearer. It lies roughly midway along a line connecting Mu Capricorni (magnitude 5.1) and 38 Aquarii (magnitude 5.4), both of which show up clearly through binoculars. This location nearly matches Neptune's position the night Johann

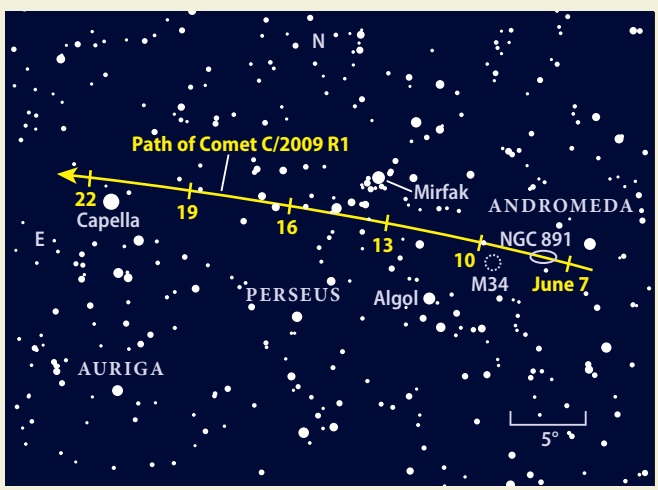
Comet search

Catch summer's splendid souvenir

Northern observers have waited a long time to see a naked-eye comet with a distinct tail. With any luck, the wait will end this month. For Comet C/2009 R1 (McNaught), start off with your unaided eyes, follow up with a view through binoculars, and finish with a telescopic close-up. The tail should look like a celestial sword angling upward into the northern sky.

The comet will be a treat for both viewing and photography after midnight. If predictions hold, Comet McNaught should glow around 5th magnitude as it floats across the sparkling stars of Perseus in mid-June. Star cluster M34 and the Alpha Persei stellar association will nicely frame this solar system interloper. The prize shot comes the morning of June 8, when the comet's tail sweeps a veil of stardust in front of the edge-on spiral galaxy NGC 891.

Comet McNaught continues to push northward during June. It passes less than 2° above the bright star Capella June 21, the morning of the summer solstice. Unfortunately, observers living far north can't benefit from McNaught's higher position because of the all-night twilight and potential interference from noctilucent clouds.



Watch a naked-eye comet, C/2009 R1 (McNaught), glide through Perseus in mid-June. The comet should peak around 5th magnitude and sport a lengthy tail that points north. *Astronomy:* Roen Kelly

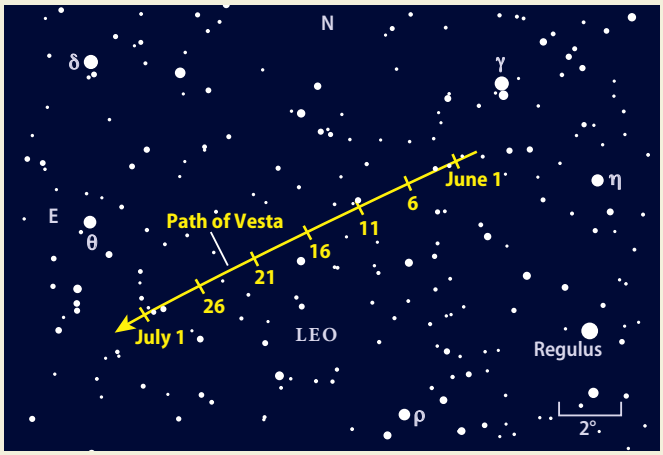
Locating **asteroids**

Countdown to a close encounter

Next summer, we will see asteroid 4 Vesta as a new world. Sharp views of this main-belt asteroid will be splashed across TV screens, newspapers, and magazines. All this will come courtesy of NASA's Dawn mission, which will reach Vesta and orbit it a year from now. But this is our last chance until then to get a good view of Vesta in the evening sky. It soon will sink into the sunset glow.

This 320-mile-wide potato-shaped minor planet glows at magnitude 7.8. That's easy for a telescope to pick up, but a bit tough for binoculars under less-than-excellent skies. The finder chart and the sparse background of stars in Leo will help you identify Vesta quickly. Only a few distant dots glow brighter than our target. A pair of 7th-magnitude stars will make the task easier the nights of June 2 and 3, when Vesta passes between the two.

Instead of star-hopping to Vesta, you can use the "coffee-break trapping method" until mid-June. Focus your scope on Eta (η) Leonis, turn off the power to your drive, and return 22 minutes later. Thanks to Earth's rotation, Vesta will drift through the field of view on cue.



Vesta tracks eastward through central Leo during June. Few stars in the immediate vicinity rival the 8th-magnitude asteroid, making it easier to pick out. *Astronomy*: Roen Kelly

Galle discovered it 164 years ago. If you point a telescope at Neptune, you'll see a blue-gray disk 2.3" across.

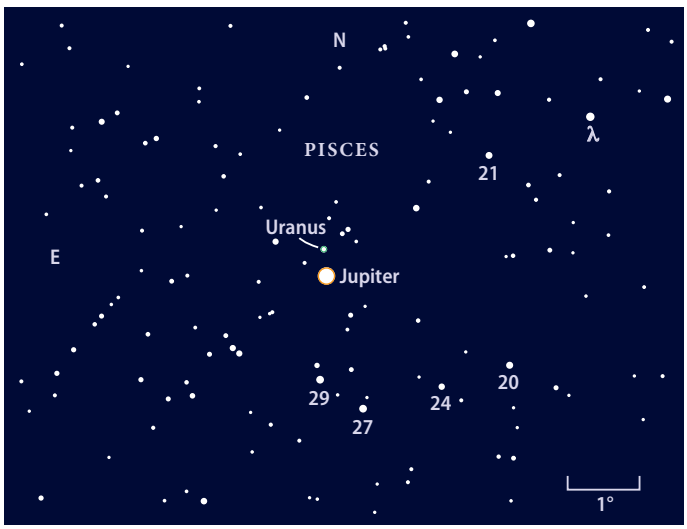
Within minutes of when Saturn sets in the west, **Jupiter** and **Uranus** rise in the east. By 3 A.M., the pair lies a respectable 15° above the horizon. Jupiter blazes at magnitude –2.4, making it the brightest point of light in the morning sky. It stands out against the faint backdrop of southern Pisces the Fish. Uranus glows at magnitude 5.9 and shows up easily through binoculars.

Throughout the first half of June, Uranus lies less than 1° from Jupiter — close enough to show up in the same low-power field of view. They are in conjunction with each other June 6. Uranus then lies 28' (about one Moon-width) due north of the giant planet. The two objects will appear in a single field through any telescope-eyepiece combination that can show the Moon's entire disk. You'll need high power, however, to resolve Uranus' tiny blue-green disk. The distant planet spans only 3.5".

Jupiter appears about 10 times larger through a telescope than Uranus. The giant planet swells noticeably during June (from 38" to 41" across) and reveals stunning detail in its cloud tops. The best time to view it is near the onset of twilight, when it appears higher and you don't have to peer through as much of Earth's image-distorting atmosphere. It also climbs higher as June progresses, so views of the planet improve quickly this month.

Jupiter's four bright moons show up easily through any telescope. Io circles Jupiter the fastest, completing one orbit every 1.8 days. Europa takes twice that long to orbit the planet, and Ganymede takes twice as long as Europa. Callisto is the slowpoke of the bunch, orbiting Jupiter once every 16.8 days. These four moons provide an endless array of changing aspects next to Jupiter.

Look for **Mercury** about 5° above the eastern horizon 30 minutes before sunrise in early June. This marks a continuation of the inner planet's morning apparition, which peaked at greatest elongation from the Sun May 25. The one advantage observers have this month is that Mercury grows brighter. The planet brightens from magnitude 0.1 to magnitude –0.6 during June's first 10 days.



Brilliant Jupiter guides you to Uranus early this month. The two appear closest around their June 6 conjunction, but they remain close neighbors for a couple of weeks. *Astronomy*: Roen Kelly

A waning crescent Moon helps guide your eye to Mercury June 10. The planet rises some 50 minutes after the easy-to-spot Moon and appears against the bright twilight sky some 8° below our satellite. Of academic interest only, the Pleiades star cluster (M45) lies 6° north of Mercury that same morning.

On June 26, for the first time since February 2008, people in much of North America will see a **lunar eclipse**. Observers in the continent's western half have a better view of this partial eclipse, which begins at 3:17 A.M. PDT. At maximum (4:38 A.M. PDT), just over half of the Full Moon's diameter lies in Earth's dark shadow. Viewers throughout the Pacific Ocean and in Australia and New Zealand can watch the entire eclipse.

What makes stars tick?

Inside most stars is a chaotic and high-energy environment. How do changes inside stars coincide with what we see?

by Liz Kruesi; illustrations by Roen Kelly

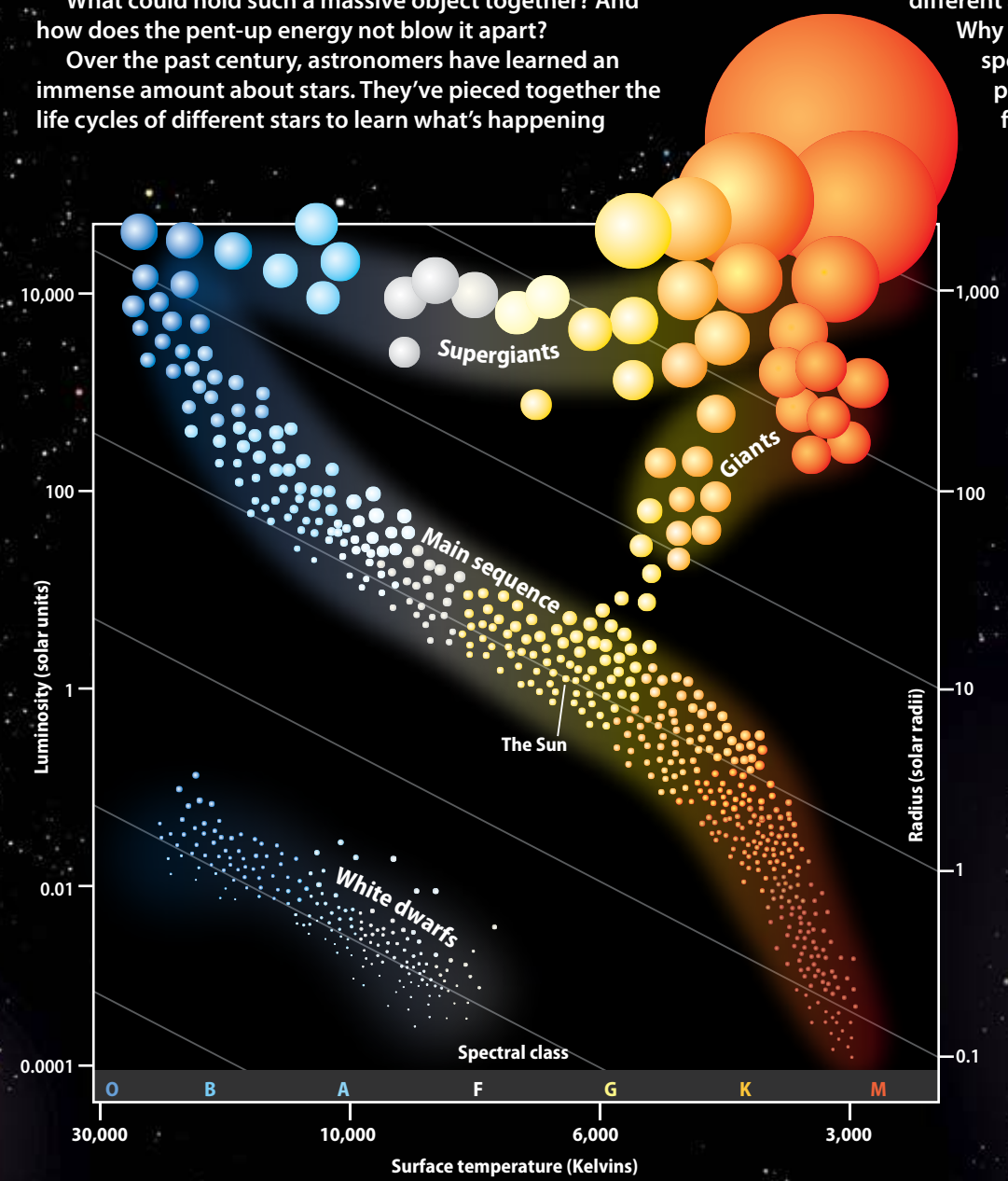
Look up at the night sky from a dark site, and you'll see tens of thousands of burning orbs of gas. Just one of those twinkling dots we call stars could be a behemoth with a mass 80 times that of our own Sun. At it's core sits a cauldron of nuclear reactions that power the star, allowing us to see it glowing from hundreds of light-years away.

What could hold such a massive object together? And how does the pent-up energy not blow it apart?

Over the past century, astronomers have learned an immense amount about stars. They've pieced together the life cycles of different stars to learn what's happening within them and how we, as observers, view each stage.

This research has shown that a star's mass dictates almost everything about the object, from the core temperature, to how long the star lives, to how it dies. While the Sun and a star 10 times its mass may have similarities during the "adult" stages of their lives, they couldn't be more different as they reach the later stages.

Why do some end their lives in spectacular blasts while others puff away their outer shells and fade slowly?

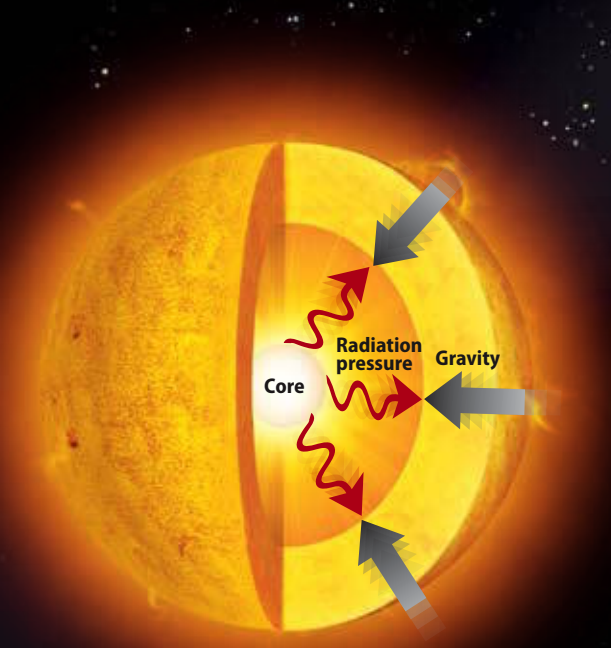


The Hertzsprung-Russell (H-R) diagram

◀ The Hertzsprung-Russell (H-R) diagram is the essential manual when it comes to understanding stars. Astronomers plot stars according to their luminosities and temperatures. A star's temperature relates to its color — cooler stars are red while the hottest ones are blue. You'll also notice that more luminous stars tend to be larger. This is because luminosity depends partly on surface area.

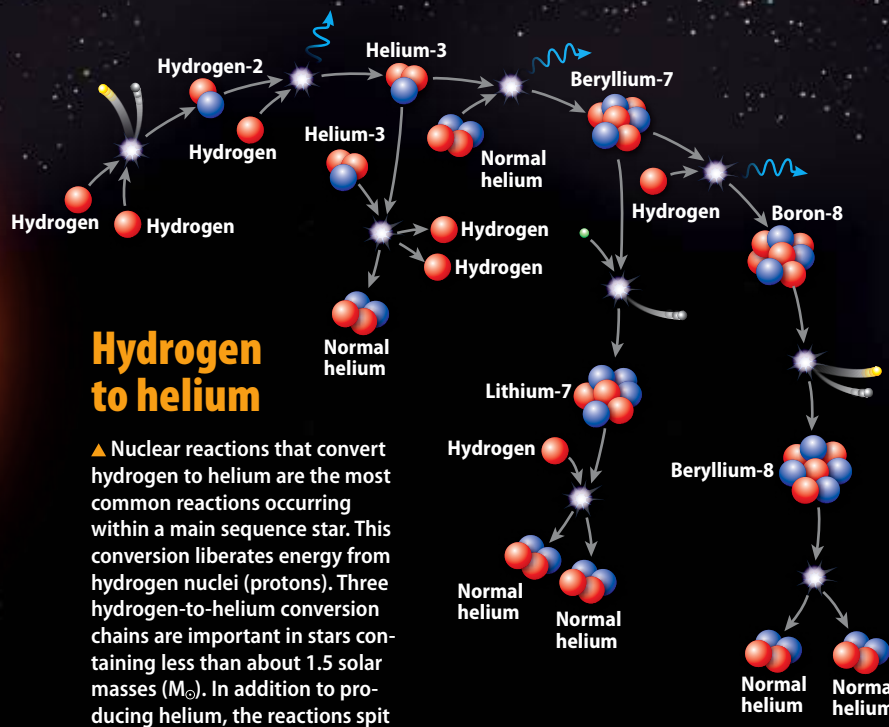
During the bulk of their lifetimes, stars fuse hydrogen into helium. Fusion is the mechanism that powers the stellar orbs. While stars undergo hydrogen fusion, they lie along the "main sequence" of the H-R diagram.

Associate Editor **Liz Kruesi** *loves high-energy astrophysics.*



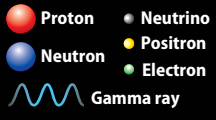
A star's important balance

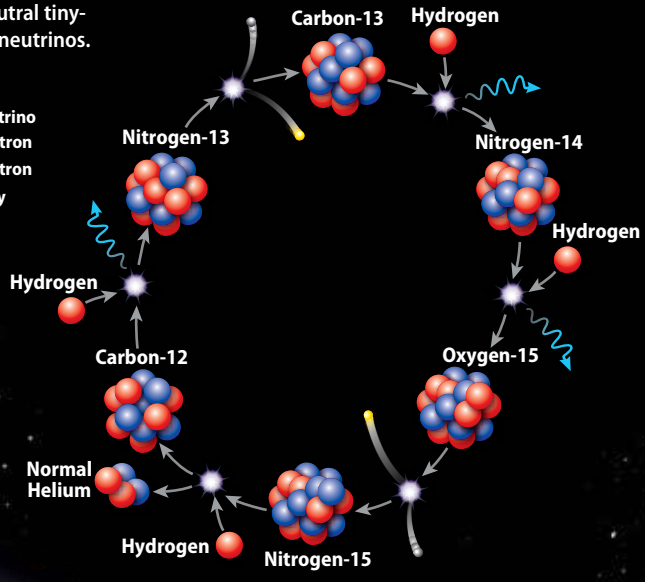
▲ Gravity pulls a star's gas toward the center. There, the pressure and temperature are so high that nuclear fusion occurs. In any star on the main sequence, protons (the cores of hydrogen atoms) fuse together to create helium. The outward radiative pressure from fusion balances the inward gravitational force.



Hydrogen to helium

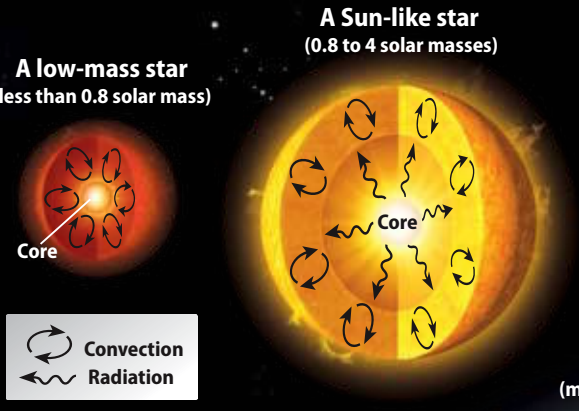
▲ Nuclear reactions that convert hydrogen to helium are the most common reactions occurring within a main sequence star. This conversion liberates energy from hydrogen nuclei (protons). Three hydrogen-to-helium conversion chains are important in stars containing less than about 1.5 solar masses ($M_\odot$). In addition to producing helium, the reactions spit out high-energy radiation (gamma rays) and neutral tiny-mass particles called neutrinos.

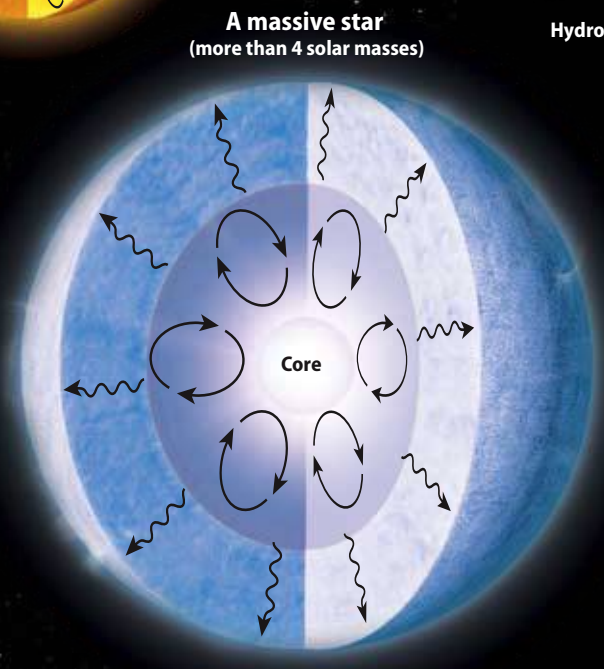




The CNO cycle

▲ A different set of reactions becomes more important in main sequence stars with cores much hotter than the Sun's core. Four hydrogen nuclei still convert to a helium nucleus, but with the help of carbon, nitrogen, and oxygen isotopes. This CNO cycle is the main reaction chain in stars greater than about 1.5 $M_\odot$.





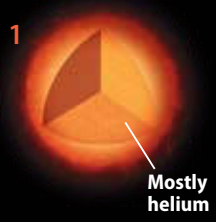
Different convective zones

▲▶ Do stars of different masses differ while they're on the main sequence? A low-mass star (less than 0.8 solar mass [$M_\odot$]) doesn't have a radiative zone — the convective zone reaches from the core to the outer layer. A Sun-like star (between 0.8 and 4 $M_\odot$) has a convective outer layer surrounding a radiative zone surrounding the core. In a high-mass star (greater than 4 $M_\odot$), the convective and radiative zones are switched.

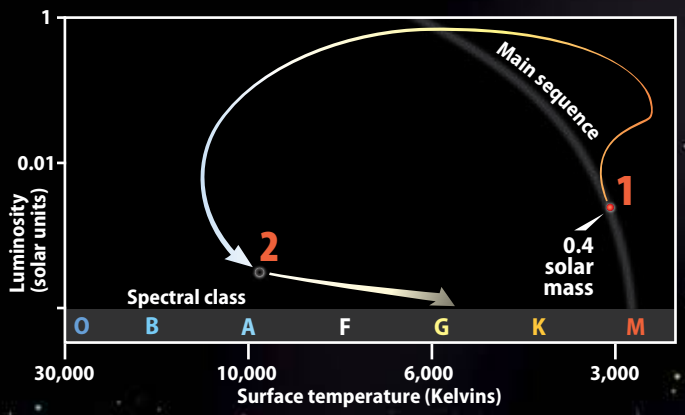
The evolution of stars

A low-mass star (less than 0.8 solar mass)

1 Like other stars on the main sequence, a star with 0.4 solar mass ($M_\odot$) will fuse hydrogen to helium at its core. However, convection runs throughout the entire star and will bring more hydrogen into the core during the star's long life.

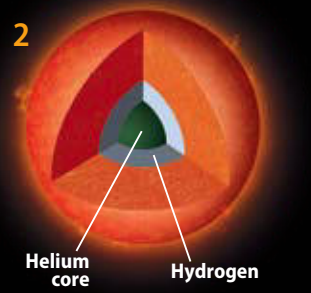


2 After about 1 trillion years, the star has used up most of its hydrogen. Nuclear fusion slows, and the reactions create less energy. Gravity pulls the outer layers toward the core. Unlike more massive stars, the core can't become hot enough to initiate helium fusion. As the star shrinks, it slowly fades and cools, eventually becoming a black dwarf.



A Sun-like star (0.8 to 4 solar masses)

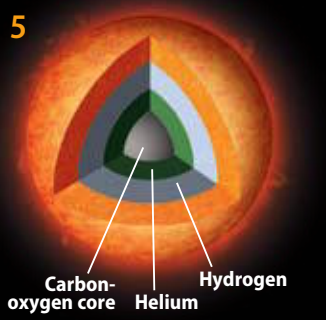
1 For some 10 billion years, a star with a mass similar to the Sun's fuses hydrogen in its core via the proton-proton reactions. Helium slowly builds up in the core, but it's not enough to begin helium fusion. The star is on the main sequence.



2 ▲ Helium has been collecting in the core, and hydrogen is mostly depleted in the inner 10 percent or so. The core begins to collapse, increasing pressure and temperature. A shell of hydrogen moves outside the core. Fusion continues around the core, and the star's layers expand. As the star grows bigger, it cools, and the star enters the red giant branch.

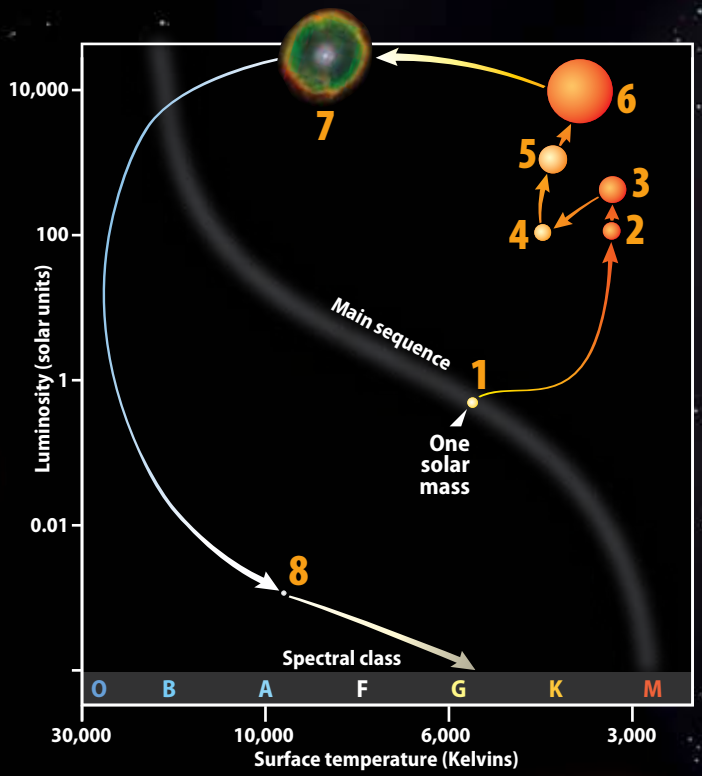
3 Fusion continues in the surrounding hydrogen shell and builds the core's mass. When the inner half of the core's mass has become nearly pure helium, the core reaches a critical temperature, which allows three helium nuclei to fuse into one carbon nucleus. This point is called the helium flash because helium fusion starts suddenly for stars less than 2.5 $M_\odot$. Stars above that threshold start fusion more gradually. Because a helium nucleus is an alpha particle, astrophysicists call this type of fusion the triple-alpha process.

4 The star now fuses helium to carbon in its core. It gets hotter and therefore becomes bluer. A hydrogen shell still surrounds the core. The star is now on the horizontal branch.



5 ▲ Carbon builds up at the core, but it's not hot enough to fuse. Occasionally, a carbon and helium nucleus will fuse to create oxygen. After between 0.1 and 1 billion years, the star has a carbon-oxygen core surrounded by a helium shell, which is still surrounded by a hydrogen shell.

6 After the core converts much of its helium to carbon, it collapses and heats up. Just as before, the star's outer layers grow larger and cool. This time, it's on the asymptotic giant branch. A star less than 4 $M_\odot$ can't get hot enough to begin carbon fusion. So the star's layers — including the hydrogen and helium shells — continue to expand.



7 ▶ Eventually, the star becomes a Mira variable, pulsating with a period of about a year. Over an astronomically brief 100,000 years, the star loses all of the material except its carbon-oxygen core. As the layers separate, they create beautiful images in the sky. A planetary nebula is the remnant outer layers from a Sun-like star.

8 ▶ An Earth-sized, white-hot core of carbon-oxygen remains. For the next hundred billion years or more, the white dwarf will gradually cool and fade.

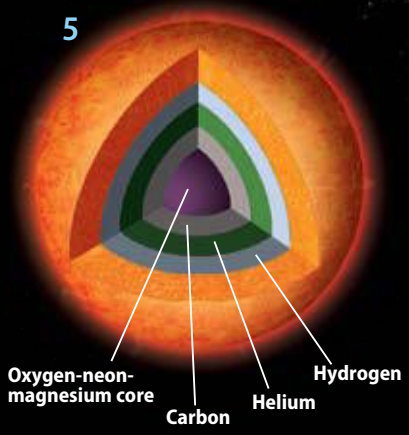
A massive star (greater than 4 solar masses)

1 Stars more massive than 4 $M_\odot$ fuse hydrogen to helium along the main sequence for between 10 and 100 million years. Whereas low-mass stars follow the proton-proton chains, these high-mass stars fuse hydrogen mostly via the CNO cycle.

2 When hydrogen fusion stops, the helium core contracts and heats up. A hydrogen shell surrounds the core. The star's outer layers puff out, and the star becomes a red supergiant.

3 The core's heat fuses helium to carbon. Then carbon and helium can combine into oxygen. Hydrogen continues burning in the shell. The star gets hotter and becomes a blue supergiant.

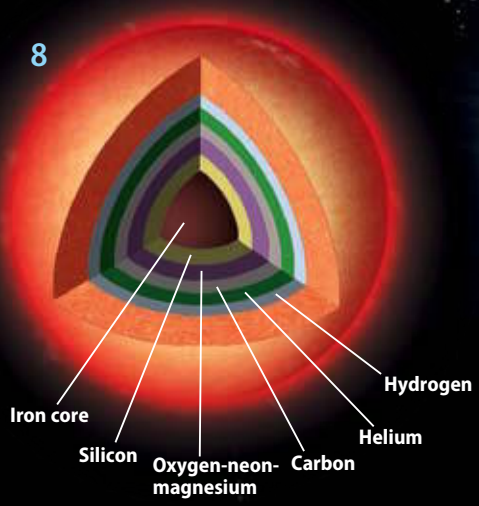
4 Eventually, the star's helium wanes at its core. The carbon-oxygen core collapses and heats up. The rising temperature initiates more fusion and therefore more energy. This pushes the outer layers farther out; as they expand, they cool. The star is again a red supergiant.



5 ▲ The temperature in the core is high enough to fuse carbon. This allows several reactions, which create oxygen, neon, and magnesium. These nuclei build up in the star's core.

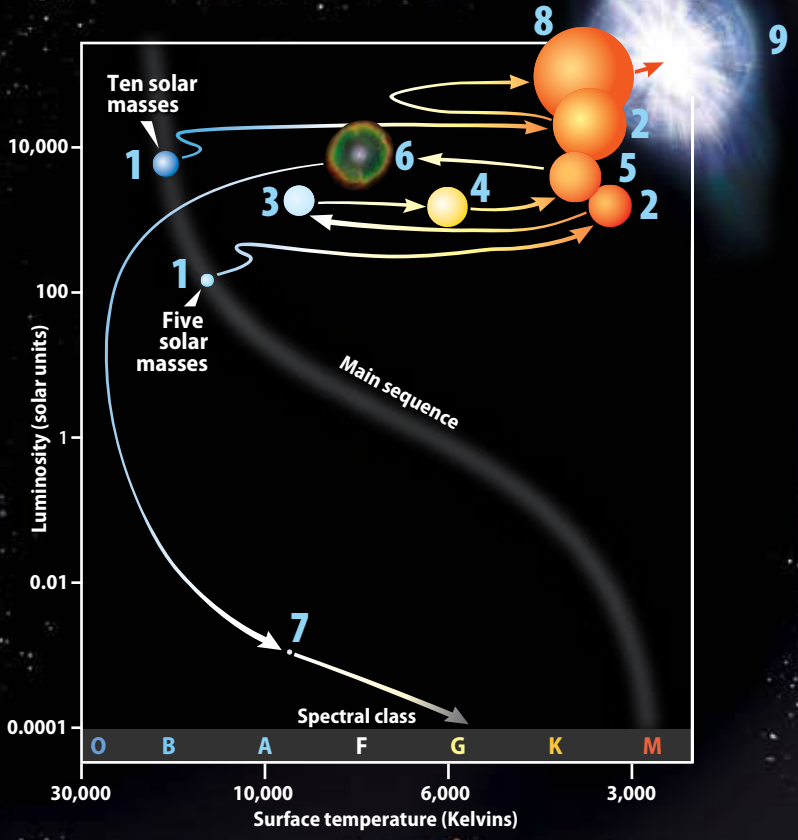
6 Only about 1,000 years pass before carbon fusion ceases. In a star less than 8 $M_\odot$, the oxygen-neon-magnesium core collapses and heats up, but not enough to initiate new fusion. The star loses all of its material (except its core) and forms a planetary nebula.

7 Over time, the oxygen-neon-magnesium core cools and fades as a white dwarf.



8 ▲ Stars greater than 8 $M_\odot$ can get hot enough to fuse neon and oxygen into additional elements. The core rapidly (a few decades) creates a silicon core, which then fuses to a nickel-iron core. The star has shells of other nuclei surrounding the heavy core.

9 ▶ Iron is the most tightly bound nucleus. So iron is the end of the road. The core begins to collapse under gravity and heats up. The star explodes as a supernova, leaving behind either a neutron star or a black hole.



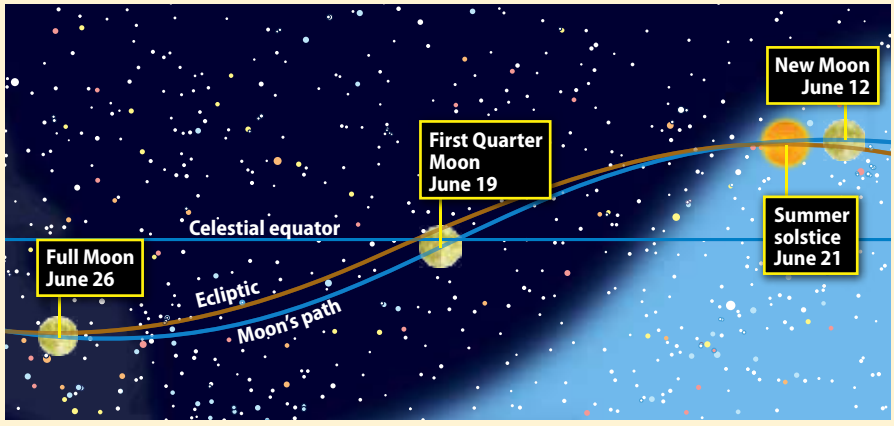
The Moon's movement

Q: It looks like the Moon stays higher in the sky on some days than on others. Why is that?
— **Holly Gilbert,** Tempe, Arizona

A: The Moon's altitude in the night sky changes during the year for two reasons: Our satellite's orbit changes relative to your horizon, and its position along this orbit changes.

That said, the Moon's orbit relative to the background stars doesn't change noticeably during the course of a single year. The track tilts 5° to Earth's orbit around the Sun (the ecliptic, which remains fixed relative to distant stars).

Because it nearly follows the Sun's path across the sky, it's easier to think about the Moon's changing altitude by considering the Sun. The Sun takes a high path across the sky in early summer and a low path in early winter. This is the driving force behind the seasons.



The Sun is at its highest point on the summer solstice (June 21), and on this date the waxing gibbous Moon appears low in the sky. Luna's lowest peak altitude in June occurs at Full Moon June 26. The Full Moon's highest point in the sky occurs in northern winter. *Astronomy:* Roen Kelly

Think first about the Full Moon. At this phase, it lies opposite the Sun in our sky. So, in early summer, the Moon inhabits the same part of the sky as the Sun does in early winter, and Luna treks low across the sky. Conversely, an early winter Full Moon travels a path that has it passing nearly overhead from mid-northern latitudes.

The same type of effect happens at other lunar phases. A First Quarter Moon appears highest in the sky after sunset in early spring and lowest in early autumn. — **Richard Talcott,** Senior Editor

THE LIVES OF GLOBULARS

Q: Why don't globular clusters ultimately collapse, rather than getting old and stable? — **Stefano Odoardi,** Denver

A: What keeps these clusters from collapsing is the angular momentum of the stars as they orbit the cluster's center of mass. It's the same physics that keeps the solar system from collapsing. However, globular clusters do evolve dynamically, albeit very slowly.

Given enough time, globular clusters will actually "evaporate." As the stars orbit the center of the cluster, they interact with each other gravitationally, and some stars will get a little boost. One by one, they will gain enough kinetic energy to escape the cluster. As the stars are expelled, the total gravitational pull of the cluster decreases, and it becomes easier for other stars to escape. The evaporation process has a snowball effect.

This process also results in something called "mass segregation": During these gravitational encounters, the more massive stars tend to migrate toward the center, and the lower mass stars migrate toward the outside or even leave the cluster. — **Kelsey Johnson,** University of Virginia, Charlottesville

MULTIPLE MOONS

Q: If Earth had more than one moon, how would it have affected life's evolution on the planet? — **Samuel Heinitz,** Edmond, Oklahoma

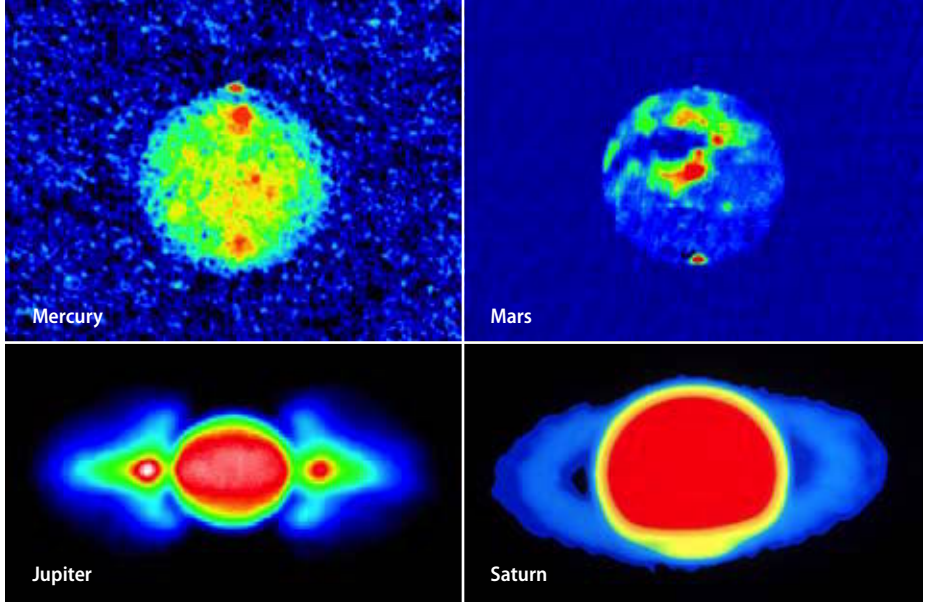
A: The Moon has played an important role in stabilizing our planet's spin axis, which probably helped prevent long-term climate changes such as those that have occurred on Mars. This question is an intriguing one to ponder at a time when we are just beginning to learn about the abundance of earthlike planets around other stars from NASA's Kepler mission.

Mercury and Venus are moonless, Mars has two tiny moons, but Earth and Pluto are the only solid worlds in the solar system that have large moons. If Earth had a second moon, it would probably be a small one, perhaps like Hydra or Nix (Pluto's lesser-known moons). **If we had such a moon, its lower mass likely would not affect our planet much other than to annoy astronomers yearning for moonless nights. Only a massive extra moon would affect Earth's tides and therefore influence the long-term stability of the planet's spin axis.**

There are a number of reasons not to expect earthlike planets to have more than one large moon. We generally believe that Luna formed from a ring

of orbiting debris liberated when a Mars-sized body impacted Earth when it was young. Only one satellite formed from this debris for the same reasons only one planet formed at our distance from the Sun: Massive bodies cannot share similar orbits because they either collide and assimilate or gravity ejects them elsewhere.

The Moon formed close to Earth. It is still migrating away as it continually gains energy from the pull of the tidal bulge it raises on Earth. An intriguing possibility to consider for earthlike planets around other stars is that a second large impact might successfully make another large satellite if it formed late enough for the first moon to have migrated far enough away to leave a space for a new one to form. — **Donald Brownlee,** University of Washington, Seattle



Mercury, Mars, and Saturn images courtesy NRAO/AUI; Jupiter: ATNF/CSIRO

Jupiter and Saturn emit strongly in radio waves, and astronomers think exoplanets should as well. (Mercury and Mars emit weaker radiation.) Unfortunately, radiation from the solar system's planets lies in the middle of the commercial radio and TV bands, making the hushed signals difficult to detect.

RADIO-WAVE SEARCH

Q: Can extrasolar planets be detected with radio telescopes and then studied via radio astronomy? — **Brian Brewer,** Ranson, West Virginia

A: Yes! Astronomers discovered the first two extrasolar planets using a radio telescope.

In 1991, Alex Wolszczan and Dale Frail were monitoring the radio signals from the pulsar PSR 1257+12 using the 1,000-foot Arecibo radio telescope at 430 megahertz. Pulsars are spinning neutron stars that emit regular radio blips, or pulses.

Sometimes the pulses from PSR 1257+12 arrived faster, sometimes slower, as the pulsar and its planets orbited their common center of mass. From the pattern in the pulses, scientists have since inferred a system of three or four planets. Two have masses a few times that of Earth's, while the other one (or two) is far less massive. Astronomers can even detect signs of the planets interacting with one other.

Wolszczan and Frail discovered the planets around PSR 1257+12 indirectly; the radio signals showed how the pulsar moves in response to the gravitational pull of its planets. But can we directly detect radio waves that extrasolar planets emit?

So far no extrasolar planets have been directly detected in radio waves. Yet many astronomers think that soon we will detect such signals. Jupiter, Saturn, Uranus, and Neptune all strongly emit radio waves where the solar wind hits their magnetospheres, and the interaction accelerates the ions and electrons. Sometimes, when the Sun's activity is low, Jupiter can outshine our star in certain radio wavelengths. This phenomenon gives us hope that extrasolar planets might give off detectable radio signals.

But the solar system's planets emit radio signals mostly in long wavelengths — around 10 to 100 feet (3 to 30 meters). Those wavelengths are in the middle of the bands set aside for radio and TV communication on Earth. To detect such faint radio waves coming from exoplanets, we need to go to isolated places or to space.

There have been a few optimistic searches for radio signals from extrasolar planets using existing radio telescopes like the Very Large Array in New Mexico, but so far astronomers have found nothing. Maybe the next generation of radio telescopes, like the LOw Frequency ARay, will be more successful. Or perhaps in the future we will build a radio telescope on the farside of the Moon. In the near term, astronomers regularly use radio telescopes to study the disks where planets form, and the more massive cousins of extrasolar planets — brown dwarfs. — **Marc Kuchner,** NASA's Goddard Space Flight Center, Greenbelt, Maryland

Send your questions via e-mail to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI, 53187.** Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

HIDDEN DIMENSIONS

Q: What is the maximum number of spatial dimensions any universe could have? — **Johnnie Smilinski,** Winnipeg, Manitoba

A: We know there are at least 3 spatial dimensions — these are the conventional X, Y, and Z directions that we are familiar with. For a long time, however, **physicists have been considering the possibility that there are dimensions additional to those three. (How many is unknown.) Those extra dimensions clearly are not visible in everyday life, but would play a role on tiny scales.**

The extra dimensions could potentially explain why gravity is so weak relative to the other three fundamental forces (the electromagnetic force we experience every day, and the weak and strong forces that play a role in holding particles and their nuclei together). If gravity "leaks" into the extra dimensions and the other forces do not, gravity would appear to us to be weaker than these other forces.

Current experiments indicate that any extra dimensions have to be smaller than about a millimeter — and thus much smaller than the three familiar dimensions. We do not currently know whether extra dimensions exist, but the Large Hadron Collider may show evidence for them in the coming years. — **Dragan Huterer,** University of Michigan, Ann Arbor

Find out the size of our solar system in light-days at www.Astronomy.com/toc.

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Choose one of these top 23 cameras to help you capture the universe.

by Michael E. Bakich

For most of the past 150 years, amateur astrophotography has been for only those who had unlimited patience and deep pockets. Then, in 1969, two scientists, Willard Boyle and George E. Smith working at AT&T Bell Laboratories, invented a small silicon wafer called a charge-coupled device (CCD). Two decades later, only a few cameras incorporating such gadgets were available. Thankfully, things have changed in the past 20 years. Now anyone interested in trying astrophotography (or, "astroimaging," as we now call it) has a variety of high-quality CCD cameras from which to choose.

CCD imagers have advantages over visual observers. Even under light-polluted skies, a small telescope with virtually any digital-imaging device will reveal details not attainable visually. If you wonder if your observing site will allow such feats, the news is better than you think.

The current crop of CCD cameras contains detectors so sensitive that you can use dense filters, which essentially eliminate light pollution. With the addition of image-processing software and some practice, your images will be good enough to appear in *Astronomy* magazine.

NASA/ESA/The Hubble Heritage Team (STScI/AURA)-ESA/Hubble Collaboration

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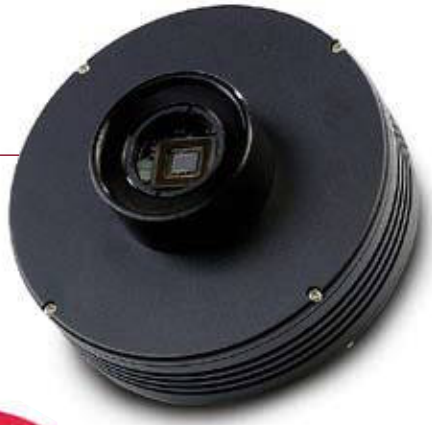
[w] www.atik-usa.com



ATIK Cameras' 16IC-S offers 16-bit conversion, low readout noise, and an ST-4-compatible autoguiding port. It accommodates a wide range of telescope focal lengths.

ATIK Cameras' 4000LE large-format camera provides full temperature regulation using a single-stage Peltier element and a fan. Its sensor chamber contains a high-efficiency dessicant.

ATIK Cameras' 314E features USB 2.0 performance, a 1 megapixel/second readout, and highly efficient thermoelectric cooling to 25° C below ambient temperature.

ATIK Cameras' 11000 comes in monochrome or one-shot color versions. Its Peltier element and fan can provide cooling to 38° C below ambient temperature, or to 45° C below ambient using cold tap water.

The first CCD cameras for amateur astronomers appeared around 1991. A CCD camera works by focusing light onto an electronic chip, which is basically an array of sensors called pixels. Each pixel converts the light falling onto it into an electronic charge in the form of a digital signal. A detector can read the signals, and software easily can manipulate them later.

CCD cameras have an advantage because they record light linearly. This means that if you double the exposure, you obtain twice the data. The proportional relationship between incoming light and electric charge is a huge improvement over the nonlinear way photographic film records images.

Now, not every astroimager has a telescope whose drive can track the sky accurately for long periods. Drive accuracy used to be crucial for accumulating enough light to record faint celestial objects. No problem! Because CCD pixels acquire light in a linear way, software will let you stack twenty 5-minute images of, say, the Iris Nebula. This produces a composite image with much better tracking accuracy than one 100-minute image. The ability to directly add images allows you to capture faint targets with exposures taken at different times or even on different nights. Some CCD images published in *Astronomy* combine dozens of hours of exposure data captured in manageable chunks 3 to 30 minutes long.

The majority of CCD cameras produce monochrome images. The simplest way to produce color pictures involves taking three separate exposures of the same object (one each through red [R], green [G], and blue [B] filters). Using software, the imager later combines the three images to form color renditions of celestial objects.

Today, less than a dozen well-known manufacturers that produce high-quality instruments dominate the field of advanced CCD imaging. For this roundup, I contacted each by e-mail and spoke to several representatives in person at conventions. Those appearing in this story sent in descriptions and images before my deadline. Thanks to all of them for helping to make astroimaging easier, more accessible, and higher in quality than it's ever been before.

Michael E. Bakich *is an* Astronomy *senior editor and the magazine's photo editor.*

FINGER LAKES INSTRUMENTATION

7298 West Main Street
Lima, New York 14485
[t] 585.624.3760
[w] www.flicamera.com

Finger Lakes Instrumentation's MicroLine ML8300 is video-mode capable and offers a peak quantum efficiency of 95 percent. Like the ProLine PL16803, the ML8300 features the RBI Annihilator. Finger Lakes offers four different shutter options with this camera.

Finger Lakes Instrumentation's ProLine PL16803 features the RBI Annihilator that eliminates ghost images common to front-illuminated full-frame cameras. The unit also has a two-port USB hub and two 12-volt power supply jacks for accessories.

THE IMAGING SOURCE

6926 Shannon Willow Road, Suite 400
Charlotte, North Carolina 28226
[t] 704.370.0110
[w] www.theimagingsource.com

Imaging Source's DMK 21AU04, like all its CCD cameras, is a cube that measures 2 inches (50.6mm) on each side. The unit weighs 9.3 ounces (256g).

Imaging Source's DMK 41BU02.H CCD camera features three frame rates, from 3.75 frames/sec to 15 frames/sec. The company includes its *Image Acquisition Components* software with all its cameras.

Imaging Source's DMK 31BU03 CCD camera is a video unit that features up to a 30 frames/sec rate. The 31BU03 has an 8-bit output and a sensitivity of 0.05 lux.

FISHCAMP ENGINEERING

105 West Clark Avenue
Orcutt, California 93455
[t] 805.937.6365
[w] www.fishcamp.com

Fishcamp Engineering's Starfish-PRO 8M has a USB interface capable of uploading images at 12 megapixels/second. A two-stage TEC cooler and an integrated fan provide cooling to 40° C below ambient temperature.

MEADE INSTRUMENTS

27 Hubble
Irvine, California 92618
[t] 800.626.3233
[w] www.meade.com

Meade's Deep Sky Imager III has a built-in temperature sensor for fast and accurate auto-dark-frame subtraction. The unit works on any scope, and you can also use it as an autoguider on AutoStar telescopes.

ORION TELESCOPES AND BINOCULARS

89 Hangar Way
Watsonville, California 95076
[t] 800.447.1001
[w] www.oriontelescopes.com

Orion's StarShoot Pro V2.0 Deep Space Color CCD prevents condensation on the optical window by virtue of increased distance between it and the CCD chip. *Maxim DL Essentials* software comes with the unit for total control of focusing, image capture, and image processing.

Orion's Parsec 8300C is a color CCD camera with an internal full-frame 32-megabyte memory buffer. The unit also has a removable 2" nosepiece.

Orion's StarShoot Deep Space Monochrome Imager III features TEC cooling, an integrated cooling fan, and an aluminum heat sink camera body. This combination can cool the camera to 30° C below ambient temperature.

Orion's Parsec 8300M features an internal shutter, which means the camera can take dark frames automatically without the user covering the telescope.

QUANTUM SCIENTIFIC IMAGING

34145 Pacific Coast Highway, #512
Dana Point, California 92629
[t] 888.774.4223
[w] www.qsimaging.com

Quantum Scientific Imaging's 500 series is a family of medium-format thermoelectrically cooled CCD cameras with high dynamic range, linear response, and a range of CCD chips.

Quantum Scientific Imaging's 532ws CCD camera employs a full-frame CCD sensor with microlens technology. Typical cooling is 38° C below ambient temperature with the unit's fans and 45° C below ambient temperature with optional liquid cooling. The 532ws offers 16 bits of digital resolution.

SANTA BARBARA INSTRUMENT GROUP

147-A Castilian Drive
Santa Barbara, California 93117
[t] 805.571.7244
[w] www.sbig.com

Santa Barbara Instrument Group's ST-8300M CCD camera has both antiblooming and microlens technology to improve the effective quantum efficiency of the sensor. The body accepts C-mount and 35mm Nikon camera lenses.

Santa Barbara Instrument Group's STL-11000M features a dual-head self-guiding option, simplified power requirements, and an internal 2" filter wheel to reduce system weight.

Santa Barbara Instrument Group's ST-8XME features a peak quantum efficiency of nearly 85 percent and multiple antireflective coatings on the CCD window for increased light transmission.

Santa Barbara Instrument Group's STX-16803 offers both simultaneous and differential guiding. The camera has a full-frame image buffer and multiple A/D channels.

23 great CCD cameras for your astroimaging pleasure

CAMERA	CHIP	CHIP SIZE	PIXELS	PIXEL SIZE	POWER REQUIRED	MINIMUM EXPOSURE	MAXIMUM EXPOSURE	PRICE
ADIRONDACK VIDEO ASTRONOMY								
StellaCam3	ICX418ALL	12.7x12.7 mm	811x508	8.4x9.8 microns	12v DC; 2.16W	0.0005 second	unlimited	$1,245
APOGEE INSTRUMENTS								
Alta U16M D9F	Kodak KAF-16803	36.8x36.8 mm	4096x4096	9x9 microns	40 Watts, max.	0.030 second	183 minutes	$9,896
ATIK CAMERAS								
16IC-S	Sony ICX415AL	7.48x6.15 mm	782x582	8.3x8.3 microns	12v DC; 0.55A	0.001 second	unlimited	$901
314E	Sony ICX205AL	7.6x6.2 mm	1392x1040	4.65x4.65 microns	12v DC; 0.55A	0.001 second	unlimited	$1,076
4000LE	Kodak KAI-04022	16.67x16.05 mm	2048x2048	7.4x7.4 microns	12v DC; 0.55A	0.001 second	unlimited	$3,522
11000	Kodak KAI-11002	37x26 mm	4008x2672	9x9 microns	12v DC; 0.55A	0.001 second	unlimited	$5,730
FINGER LAKES INSTRUMENTATION								
ProLine PL16803	Kodak KAF-16803	36.8x36.8 mm	4096x4096	9x9 microns	12v DC	0.006 second	200 minutes	$10,495
MicroLine ML8300	Kodak KAF-8300	17.96x13.52 mm	3326x2504	5.4x5.4 microns	12v DC	0.040 second	200 minutes	$3,595
FISHCAMP ENGINEERING								
StarfishPRO 8M	Kodak KAI-08050	6.83x5.45 mm	3296x2472	5.2x5.2 microns	5v DC / 12v DC	25 frames/sec	3.5 frames/sec	$3,495
IMAGING SOURCE								
DMK 21AU04	Sony ICX098BL	4.6x3.97 mm	640x480	5.6x5.6 microns	5v DC; 0.5A	0.0001 second	30 seconds	$390
DMK 31BU03	Sony ICX204AL	5.8x4.92 mm	1024x768	4.65x4.65 microns	5v DC; 0.5A	0.0001 second	30 seconds	$650
DMK 41BU02.H	Sony ICX205AL	7.6x6.2 mm	1280x960	4.65x4.65 microns	5v DC; 0.5A	0.0001 second	30 seconds	$710
MEADE								
Deep Sky Imager III	Sony ICX285AQ	10.2x8.3 mm	1360x1024	6.45x6.45 microns	USB 2.0 port	0.0001 second	1 hour	$799
ORION								
StarShoot Deep Space Mono-chrome Imager III	Sony ICX285AL	10.2x8.3 mm	1392x1040	6.45x6.45 microns	12v DC	0.002 second	100 minutes	$1,499.95
StarShoot Pro V2.0 Deep Space Color CCD	Sony ICX413AQ	25.1x17.64 mm	3032x2016	7.8x7.8 microns	12v DC	0.002 second	9.3 hours	$1,399.95
Parsec 8300M	Kodak KAF-8300-AXE	17.96x13.52 mm	3326x2504	5.4x5.4 microns	12v DC	0.002 second	unlimited	$2,599.95
Parsec 8300C	Kodak KAF-8300-CE	17.96x13.52 mm	3326x2504	5.4x5.4 microns	12v DC	0.002 second	unlimited	$2,499.95
QUANTUM SCIENTIFIC IMAGING								
QSI 532ws	Kodak KAF-3200ME	14.85x10.26 mm	2184x1472	6.8x6.8 microns	12v DC; 1.5A	0.03 second	240 minutes	$6,590
QSI 516ws	Kodak KAF-1603ME	13.8x9.2 mm	1536x1024	9x9 microns	12v DC; 1.5A	0.03 second	240 minutes	$4,590
QSI 520ws	Kodak KAI-2020M	11.84x8.88 mm	1600x1200	7.4x7.4 microns	12v DC; 1.5A	0.0001 second	240 minutes	$3,890
SANTA BARBARA INSTRUMENT GROUP								
ST-8300M	Kodak KAF-8300	17.96x13.52 mm	3326x2504	5.4x5.4 microns	12v DC; 3A	0.1 second	3,600 seconds	$1,995
ST-8XME	Kodak KAF-1603ME	13.8x9.2 mm	1530x1020	9x9 microns	5v DC; 1.5A	0.12 second	3,600 seconds	$2,995
STL-11000M	Kodak KAI-11002M	36x24.7 mm	4008x2672	9x9 microns	12v DC	0.001 second	3,600 seconds	$5,995
STX-16803	Kodak KAF-16803	36.8x36.8 mm	4096x4096	9x9 microns	12v DC; 6A	0.1 second	3,600 seconds	$11,875

How an amateur astronomer captured a black hole scoop

When **Stephen G. Cullen** *imaged Cygnus X-1 in May 2009, he discovered the effect this black hole has on its neighborhood.*

Cygnus X-1's name sounds like it could come right out of one of the episodes of *Battlestar Galactica*. In reality, it is the designation astronomers gave to the first black hole candidate. It lies in the constellation Cygnus the Swan. Initially detected in 1964, Cygnus X-1 strongly emits X-rays.

Astronomers debated the nature of the emissions for a decade. They finally agreed that a black hole and the blue supergiant star HDE 226868 orbiting a common center of mass fit the observations. Researchers have kept an eye on Cygnus X-1 ever since and developed a model of how the system functions.

What's going on here?

One theory says material from the blue supergiant's surface carried away by its stellar wind serves as fuel to power the black hole. Some of the matter enters jets emanating from the black hole's north and south poles. The jets beam the material, at around 60 percent of light speed, as far as 20 light-years in either direction.

Unfortunately, the jets are also poor radiators of energy, so they are virtually impossible to detect with current instruments. Instead of seeing the jets directly, we have to infer their existence by the impact they have on their environments. Luckily, Cygnus X-1 inhabits a region of space thick with gas that emits specific kinds of radiation when hit by shock waves, energetic particles, and relativistic jets from black holes.

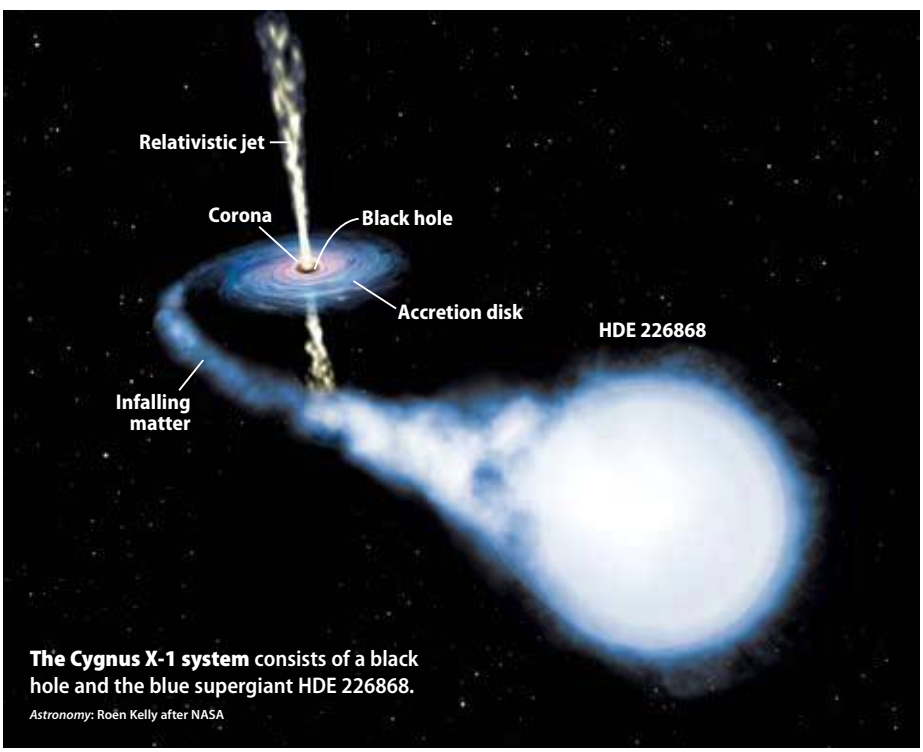
An amateur astronomer steps up

About a year ago, I became interested in Cygnus X-1 and immersed myself in the scientific literature to get up to speed. As an amateur astronomer, many of the details were a chore to understand, but I was able to grasp things on a conceptual level. The most recent paper I read on Cygnus X-1 was by David Russell, a postdoctoral astronomer at the Astronomical Institute of the University of Amsterdam.

Russell and his team were the first to show visual evidence of a jet-powered nebula caused by the northern jet slamming into the interstellar medium. As the jet collides with the gas, it forms a bow shock the way a boat's hull creates a bow wave as it slices through water. The team's published images were intriguing, but the astrophotographer in me thought they could be better. I also wondered why no one had found similar evidence for a southern jet. I now had a mission.

I am fortunate to have access to the LightBuckets 24-inch RC Optical Systems Ritchey-Chrétien telescope. The telescope's camera is an Apogee Alta U42 with a quantum efficiency over 90 percent. I knew it would be a challenge to surpass Russell's imaging given that he used the 2.5-meter Isaac Newton Telescope on La Palma in the Canary Islands, an instrument with nearly 17 times the light-gathering power of mine. I had an ace in the hole, though — time on target.

Most institutional telescopes have long queues of astronomers waiting for a small window of time on the instrument to gather data. Russell's imaging consisted of just 40 minutes of exposures each through Hydrogen-alpha and Oxygen-III filters. I reasoned that if he was able to apply 4 times the aperture to the task, then I should apply 4 times the imaging duration.



The Cygnus X-1 system consists of a black hole and the blue supergiant HDE 226868.
Astronomy: Roen Kelly after NASA

Stephen G. Cullen *is the president and CEO of LightBuckets online telescope rentals. He's also a dedicated astroimager.*

Over the course of four evenings in May 2009, I trained the LightBuckets telescope on the northern region of Cygnus X-1 and captured eleven 15-minute images each through Hydrogen-alpha, Sulfur-II, and Oxygen-III filters. Right away it was clear that I had acquired terrific data with the bow shock's nebulosity apparent in all three bandwidths. Each of these emissions, besides contributing to a beautiful false-color image of the nebula, are important indicators of exactly what is happening when the jet collides with the denser gas.

A professional connection

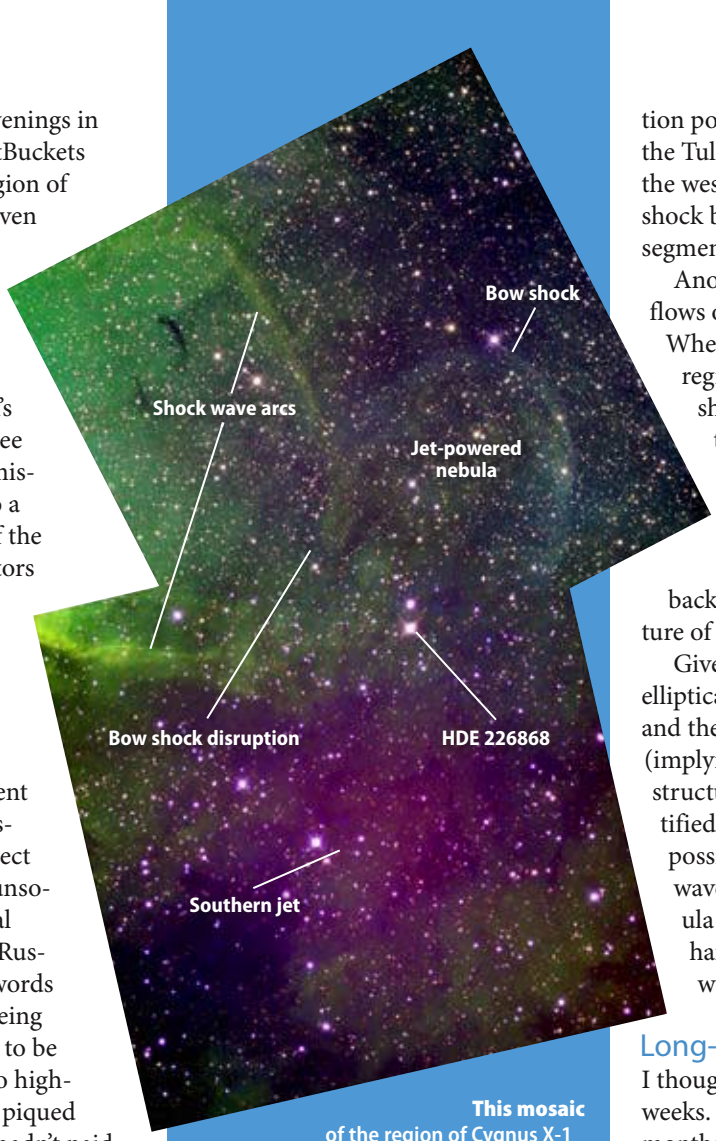
Eager to share my results, I sent my images with a note to Russell. I wasn't sure what to expect because I had never sent an unsolicited e-mail to a professional astronomer. To my surprise, Russell responded quickly with words of encouragement, even agreeing that the image data appeared to be better than his. He went on to highlight features in my data that piqued his interest — information I hadn't paid much attention to.

I went back and reprocessed my data to enhance Russell's areas of interest. Nothing significant stood out, and I put the northern region aside, content that I had accomplished that particular goal.

The next step, the southern jet search, was like looking for a specific needle in a stack of needles. Fortunately, research constrained where the jet could meet up with the interstellar medium by producing a good theory of the "opening angle" for the jets. This led me to search on a line from the source southward.

I began by imaging the region immediately to the southeast of Cygnus X-1, devoting 4 hours of exposure through each of the three filters. Unlike the northern region, the images did not show a well-defined shell of shocked gas.

What I did see, however, was a diffuse, fan-shaped glow that traced a path directly back to Cygnus X-1. When I shared these new findings with Russell, he believed I had likely produced the first evidence of the southern jet of Cygnus X-1. He also struggled to explain the mechanisms at work.



This mosaic of the region of Cygnus X-1 and the Tulip Nebula shows the interaction between the bow shocks from the black hole's jets and the surrounding interstellar medium. Stephen G. Cullen/LightBuckets

A possible explanation

Things turned even more interesting once I combined my data from the northern and southern regions of Cygnus X-1. When I first imaged the northern region, I noted the filaments and the possible multiple shock waves that the literature described. What stood out was what appeared to be two arc segments that would normally create a complete semicircular shape had it not been disrupted at its western edge. The disrupting agent seems to be the backflow from the Cygnus X-1 bow shock.

The northern section of the shock wave arc is mostly intact from the disruption point on the west side until it meets the Tulip Nebula (Sharpless 2–101). At the western edge, it appears that the bow shock backflow has cleanly dissociated a segment of the arc.

Another section of the shock wave arc flows out from Sh 2–101 westward. Where the arc reaches the backflow region, it too disrupts, and the shocked gas seems to be drawn into the nebula's cocoon. Computer simulations of relativistic jets and their related bow shocks predict that exactly this type of mixing can occur due to the backflow and eventual turbulent structure of the cocoon.

Given the shape of the arcs, the highly elliptical structure they originated from, and their strong Sulfur-II line emissions (implying shocked gas), I believe the ring structure is part of a previously unidentified supernova remnant. It is even possible that the supernova's shock wave is responsible for the Tulip Nebula and the star-forming regions it harbors, but confirming this idea will require more research.

Long-term commitment

I thought this project would last a few weeks. It now has spanned nearly 8 months. I never dreamed that the professional community would be so willing to work with amateur astronomers. I now realize that the people who do research for a living face challenges in their efforts that amateurs can help with. And, as online telescope services like LightBuckets continue to expand, both amateurs and professionals can gain ready access to research-caliber instruments under pristine skies at a moment's notice.

Russell and I are in the process of merging our data with the goal of comprehensively analyzing the Cygnus X-1/Sh 2–101 complex and publishing our findings in the not-too-distant future. I suspect we'll also continue to collaborate on stellar-mass black hole research now that I've shown that even relatively small instruments (compared with what the pros use) can provide valuable and unique data.

See the author's images of the Cygnus X-1 region through each filter and more at www.Astronomy.com/toc.

Amplify your view of the night sky

Night Vision Astronomy's Binocular Photon Machine will triple your telescope's aperture through electronics.

by Tom Trusock

Night Vision Astronomy's Binocular Photon Machine is a light-amplification device that you can hold or attach to a telescope focuser.

I've long wanted to own an extremely large telescope, but the size, weight, and expense have put me off. Something that's intrigued me, though, is the capability provided by using a light-amplification device as sort of an aperture multiplier.

Night Vision Astronomy from Pound Ridge, New York, now offers an instrument that uses such technology. The Binocular Photon Machine (BIPH) is a third-generation light-amplification unit the company has modified for astronomical use. It's available in two flavors: one featuring a brand new night vision tube and a 2-year warranty for $3,995, or a model like I tested with a clean used tube and a 1-year warranty for $3,299.

First impressions and specs

Stored in its included hard-shell case, the BIPH is a rather unimposing piece of equipment. It's small and lightweight, about the size of a binoviewer with eyepieces, which makes it an easily portable device. Two AAA batteries power the BIPH and provide approximately 40 hours of operational time.

The night vision tube has an optical window that lets you view the phosphorescent green image with both eyes (and from seemingly any distance). With this setup, eye relief is not an issue. One available option is a Hydrogen-alpha filter system. Another is an SLR camera lens adapter. Both came with my test rig.

The specifications on the BIPH say that you'll get a net gain of around 50,000 in light amplification. My tests showed this translated to an effective aperture gain around 3x, but gauging that was tricky. The BIPH, like all night amplification devices, is more sensitive to longer wavelengths such as red light and infrared than to shorter wavelengths like blue light. The aperture gain, therefore, isn't equal across different targets.

Accessories for the BIPH include camera lens adapters for hand-held operation and a Hydrogen-alpha filter (below) for use under a bright sky. All photos: *Astronomy*: William Zuback

Pointing the BIPH skyward

The BIPH worked best on globular clusters and emission and planetary nebulae. And I made a surprising find. Many globulars that I thought were resolution-limited through a particular telescope were actually light-limited. In other words, although the BIPH increases the light grasp of a 3-inch scope to that of an effective 9-inch telescope, you're still working with the resolution capability of a 3-inch instrument. When I was viewing globular cluster M22 through a 3-inch

Contact information

Night Vision Astronomy
7 Old Snake Hill Road
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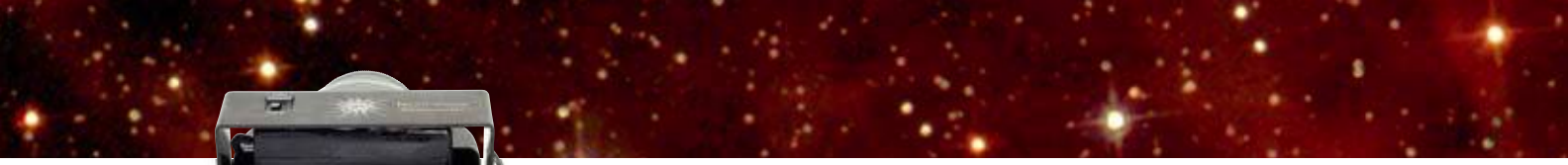
[t] 646.772.4138
[w] www.nightvisionastronomy.com



The Hubble Heritage Team (AURA/STScI/NASA)

The front of the BIPH (left) sports a nosepiece that fits 2" focusers. An optional 1¼" adapter is available. The rear (far left) of the unit's port lets you use both eyes to view the phosphorescent screen. The BIPH measures 9 by 5 by 3 inches (22.9 by 12.7 by 7.6 centimeters).

Specifications

Photocathode: Gallium arsenide
Output screen: P43 phosphor
Luminous gain: 40,000 to 70,000 at 0.000002 foot-candles
Resolution: 64 lines/millimeter
Power: Two AAA batteries (40 hours)
Nominal tube life: 10,000 hours
Telescope adapter: 2" nosepiece (1¼" adapter available)
Price: $3,995 new; $3,299 used

scope from the dark skies of the American West, however, the BIPH resolved it clear across its face.

I also had the opportunity to try the BIPH with a couple of camera lenses. With small, lightweight lenses, I handheld the setup easily, and it provided a unique view of the night sky. I've seen the North America Nebula (NGC 7000) at low powers before, but I've never seen it this well defined. Because the BIPH works well into the infrared range, I also had great views of many dark nebulae strewn across the summer Milky Way.

Getting the most from it

I used the BIPH on several different telescopes of varying design, and while it worked on all, it worked best on well-baffled systems. The BIPH is sensitive to stray light. While observing through a 30-inch reflector from a dark site, I had no issues whatsoever. However, using my observatory-based 18-inch reflector, I had to turn off all red lights to maintain good image contrast. Under the same conditions, I found I didn't have to make any such concession with various refractors or Schmidt-Cassegrain telescopes.

If you've never used night-vision technology, you might find the view through the BIPH is not quite what you're accustomed to. It's more like looking at a computer monitor than it is traditional observing. The image it presents is green. Green is the choice because the eye is capable of differentiating between more shades of green than any other available phosphorescent color.

Depending on the telescope's focal ratio, some noticeable scintillation (twinkling akin to static on a TV) may be present in the system. Long-focal-ratio instruments can reduce the light received. I wondered whether the green glow would degrade my dark adaption. While there were some effects, I found them noticeable only when switching back and forth between amplified and natural views. In some respects, using the BIPH is similar to astroimaging, but there's no integration time, so images display immediately, and you don't require a tracking mount.

To use the BIPH is to love it

I wish the BIPH amplified the full spectrum of light evenly, but that's unfortunately a byproduct of current night-vision technology. And, while it is on the expensive side, it's perfect for outreach. What's more, it can make city-based deep-sky observing more satisfying. Finally, it's a superb addition to your travel kit. If at all possible, try the BIPH before you buy it. Once you know what you're getting into, you'll be a satisfied amateur astronomer seeing objects you didn't think possible before.

The BIPH comes in a padded, watertight case (Model 1450 Pelican) that protects the device and any accessories you store with it.

Tom Trusock *is a prolific telescope reviewer who observes from rural Michigan.*

Secret Sky

by Stephen James O'Meara

Phantasmagoria: transient luminous events

Seeing strange lights in the sky doesn't necessarily mean you're imagining things.

Summer is upon us. With it comes the promise of hot days and, occasionally, sky-splitting lightning. But did you know that, under the right conditions, distant thunderstorms can also produce an array of eerie light spectacles?

These displays, called transient luminous events (TLE), form above the storms against a starlit nighttime sky. They appear as whimsical phantom shapes — doughnuts, trees, comet tails, and jellyfish, for example — that flash in and out of view in the blink of an eye. Seeing one has caused some observers (including me) to rub their eyes in disbelief.

But trust me, they're there! Amateur astronomers and astronauts alike have spied them. Thousands have appeared in photographic and video documentation. They literally materialize and vanish, out of and into thin air, in the middle and upper atmosphere. And with a little planning and luck, you too just might see (or image) one or more of these phantasmagorical light shows. They play with not just the sky, but also your mind.

The TLE zoo

TLE researchers at the University of Alaska in Fairbanks have classified several events based on their appearances. Here are some of the most popular phenomena:

"Red sprites" appear in the sky as inverted teardrop-shaped bodies, below which hang blue filamentary "tendrils." The most complex and dramatic TLE, sprites occur directly above active thunderstorm systems, to altitudes up to around 60 miles (100 kilometers). They are coincident with large, positive cloud-to-ground lightning strokes. Most sprites occur in clusters of two or more, giving them a shape reminiscent of a jellyfish, carrots, or a burning tree. The events last for only a few milliseconds, thus appropriately reflecting their namesake: the whimsical and fleeting air spirit Ariel in Shakespeare's *The Tempest*.

The author saw his first sprite on December 5, 2005. He created this photo-illustration (the stars shown here were not the real stars he saw the phenomenon against) to demonstrate the dim object's appearance and superlative size. "Seeing this 'phantom jellyfish' made me question my sanity," the author jokes. "It was that freakish." Stephen James O'Meara

"Sprite halos" are diffuse rose-colored glows that occasionally surround the bright cores of sprites. Halos may also precede sprites, lasting but a millisecond.

"Gigantic jets" resemble sprites, but they're not directly associated with cloud-to-ground lightning. Instead, they tend to propagate upward from the core of oceanic thunderstorms. Gigantic jets are among the brightest TLEs and can last nearly a full second.

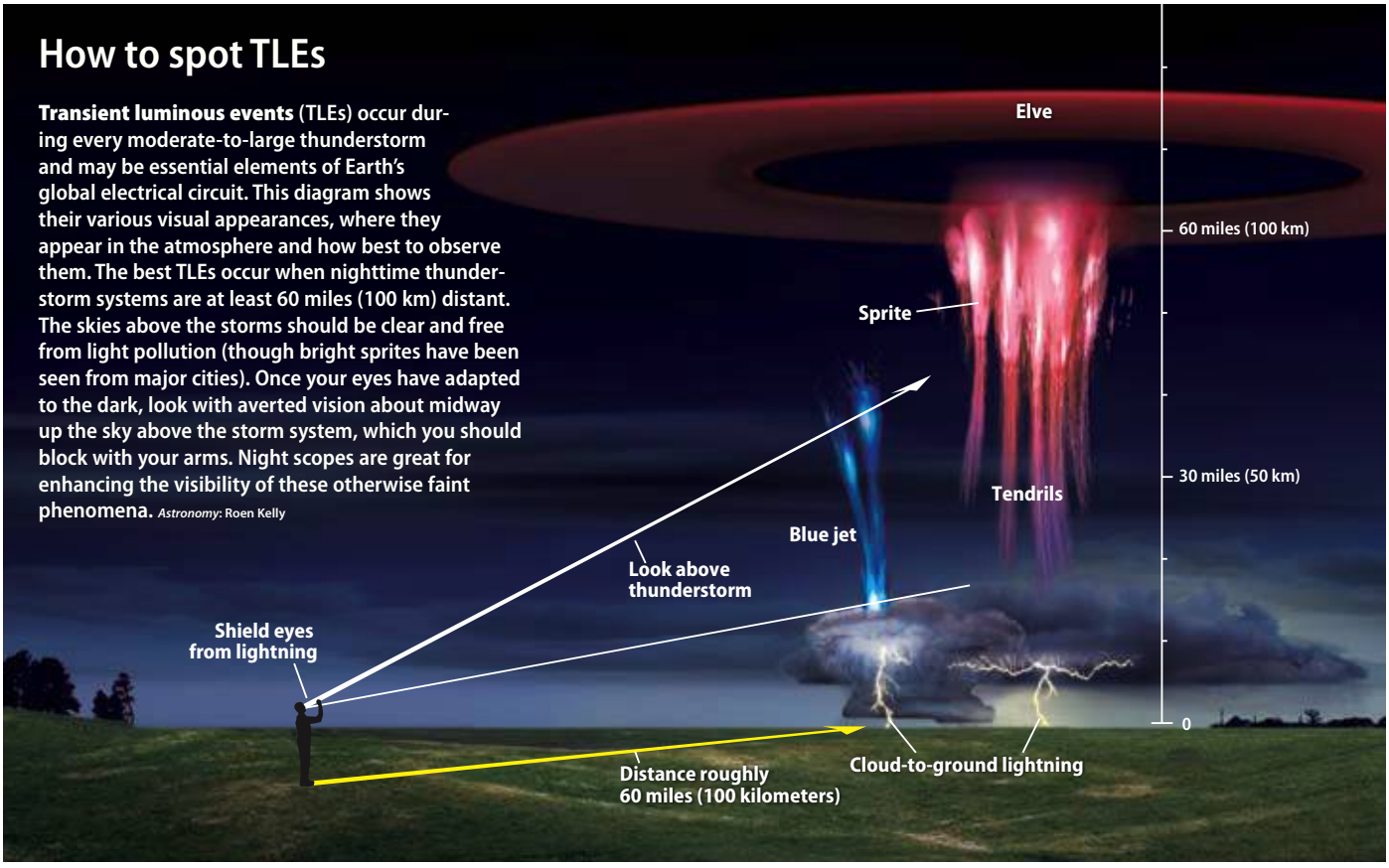
"Elves" appear as rapidly expanding doughnuts of light that vanish in less than a millisecond. They most likely result when an electromagnetic pulse from an energetic cloud-to-ground lightning strike propagates into the ionosphere. While elves may accompany sprites, the mechanisms that create the two differ.

"Blue jets" look like long and fanning comet tails that flash upward from the top of a thunderhead (from the electrically active core) at speeds of about 60 miles (100 km) per second. Each event lasts a few tenths of a second — a long time compared to sprite-related events. They're also brighter than red sprites. Lightning doesn't seem to trigger them directly, but they do have a strong correlation with hail activity in thunderstorms.

"Trolls" resemble blue jets, but are red and appear after tendrils of strong sprites extend downward toward the cloud tops.

Personal accounts

I saw my first TLEs December 5, 2005, from my home in Volcano, Hawaii. After a severe thunderstorm awakened me at 3:30 A.M., I went outside and saw crystal-clear skies. But every 5 to 10 seconds, I also saw flashes illuminate a band of clouds 10° above the southeastern horizon. Blocking the flashes with my arms, I looked at the stars about halfway up the sky. After 10 minutes, I suddenly saw a phantom jellyfish, 15° in length, flash in


How to spot TLEs
Transient luminous events (TLEs) occur during every moderate-to-large thunderstorm and may be essential elements of Earth's global electrical circuit. This diagram shows their various visual appearances, where they appear in the atmosphere and how best to observe them. The best TLEs occur when nighttime thunderstorm systems are at least 60 miles (100 km) distant. The skies above the storms should be clear and free from light pollution (though bright sprites have been seen from major cities). Once your eyes have adapted to the dark, look with averted vision about midway up the sky above the storm system, which you should block with your arms. Night scopes are great for enhancing the visibility of these otherwise faint phenomena. Astronomy: Roen Kelly
Elve
60 miles (100 km)
Sprite
Tendrils
30 miles (50 km)
Blue jet
Look above thunderstorm
Shield eyes from lightning
0
Distance roughly 60 miles (100 kilometers)
Cloud-to-ground lightning

and out of view. I perceived no color in this sprite. Most curiously, although the physics behind the phenomenon suggests it lasts for just a few milliseconds, the visual/mental impression against the sky seemed to linger for about 1.5 seconds.

Five minutes later, as I looked about one-third of the way above the eastern horizon, another flash occurred. I saw an afterimage of my retina projected against the stars. But I also observed, to its lower right, a distinct flare of blue light, which formed a ball about 1° in apparent diameter. No other events occurred in the half-hour of observing.

More recently, on the evening of November 11-12, 2009, yet another distant thunderstorm (which threatened to dump snow and hail on Mauna Kea) produced broad flashes that appeared as a pretty pastel-blue dome above my northern tree line. Occasionally, three blue "comet tails" 15° long would appear in concert with the dome, looking like auroral streamers.

Were these blue jets? I don't know. I didn't see them dash upward, just their long forms connected to the blue dome.

Browse the "Secret Sky" archive at www.Astronomy.com/OMeara.

So perhaps they're some other freakish phenomenon. The same storm produced a little blue crescent of light, about 1° in diameter, which I saw with direct vision just east of the North Star.

Summer and winter displays

During five separate winter thunderstorms (December 2005 through March 2006) in Israel and the Eastern Mediterranean Sea, Michal Ganot of Tel Aviv University and her colleagues detected 27 sprites (four halo sprites) and four elves. The sprites occurred almost exclusively over the sea, at altitudes between 27 and 65 miles (44 to 105 km). Most were single columns (like the "jellyfish" I had observed) and lasted, on average, about 43 milliseconds. Most of the thunderclouds that produced sprites were isolated cumulonimbus cells embedded within a matrix of lower rain clouds.

These observations support those by Taiwanese researcher Yun-Ching Wang of the National Cheng Kung University and colleagues. Since 2001, they've conducted yearly summer TLE campaigns from various locations in Taiwan. Up to 2005, their data indicate that land sprites tend to cluster while oceanic sprites tend to appear in a single column. Two extremely bright sprites were intense enough to cast reflections on the ocean or penetrate the intense light pollution of Taiwan's city Tainan. On the remarkable night of July 22, 2002, they also recorded 5 gigantic jets. They lasted 300 to 500 milliseconds and appeared above an oceanic thunderstorm near the Philippines.

TLE research has made truly astounding progress in recent years. If you ever witness one of these eerie flashes, be sure to report it to TLE researcher Matt Heavner of the University of Alaska Southeast at http://elf.gi.alaska.edu. Of course, you should also send it to me at someara@interpac.net.

The red sprite visible in this 1994 photo, captured using high-speed aerial cameras, provided the first tangible evidence that TLEs are real phenomena. D. Sentman, G. Wescott, Geophysical Institute, U. Alaska Fairbanks, NASA

Dave Kriege

Founder, owner of Obsession Telescopes

Despite being born in Cleveland, Ohio, Dave Kriege considers himself a true Wisconsinite. "I've been a Cheesehead since I was 4 years old," he says. It was in the Badger State that he first began a fascination with astronomy that would last his whole life.

"My dad and I built a 4-inch reflector for an eighth-grade science project," Kriege says. "One look at the stars with it, and I was hooked." For much of his life, though, astronomy was just an intriguing hobby. When he graduated from Milwaukee's Marquette Dental School in 1979, he became a dentist full time, but always kept an eye on the skies.

About a decade later, Kriege founded Obsession Telescopes in Lake Mills, Wisconsin, and he's stuck with it ever since. "In 1989, we introduced the first Dobsonian with large-diameter side bearings and anti-friction surfaces," he says, "resulting in finger-tip guiding and incredibly easy motion in all directions." He likes to stress that Obsession is not a factory; it produces handcrafted telescopes on a limited-edition basis. In about 20 years, Kriege's sold more than 1,500 large-aperture telescopes to observers in 20 countries.

"I just built a few scopes [in the 1980s], and I've been backordered ever since," he says.

Dave Kriege, founder and owner of Obsession Telescopes, displays the first 22-inch Ultra Compact telescope at the September 2009 Okie-Tex Star Party near Kenton, Oklahoma. Courtesy Dave Kriege

What's something cool about Obsession Telescopes that nobody knows?

My wife named the company 23 years ago. When I was building my first big Dobsonian, she said with an irritated voice that I was "obsessed with it."

"Obsession has been the most innovative large-aperture telescope-maker since we came out in 1987."

How has Obsession changed through the years?

Obsession has been the most innovative large-aperture telescope-maker ever since we came out in 1987. Everybody always copies us. After introducing the Ultra Compact (UC) series, we changed the industry once again. Our competitors are scrambling to come up with Obsession UC clones, just as they did the Obsession Classic Dobsonians.

Is Obsession your sole job now?

I'm still doing teeth part time. In 2000, I hired another dentist to work 2 days a week at my office. Now I'm down to 100 hours per week between both jobs. Dentistry is all negative, though. Nobody wants to go to the dentist. The telescope biz is all positive. People love to send me money for a scope. It's all fun and no stress.

What are some of your most popular products?

Our large-aperture UC telescopes remain very popular. We recently added a 22-inch UC to our product line, which features a large aperture that fits in nearly any vehicle.

Do you personally enjoy observing?

I'm a hard-core observer and enjoy all deep-sky objects. My personal scope is a 25-inch f/5. I've hauled it to dozens of primo dark sky sites throughout North America. I've also taken an 18-inch UC to Australia to observe the southern sky.

Can you share anything about upcoming products?

We will likely continue to expand the Ultra Compact series. I also plan to update my and Richard Berry's book, *The Dobsonian Telescope*, to include more innovations and the Obsession Ultra Compact design.

Where, in your opinion, is the hobby headed?

Definitely ultra-compact telescopes. Everyone wants a big scope that fits in the back seat of their car.

New Products

25x binoculars

Celestron
Torrance, California

Celestron's SkyMaster 25x70 binoculars employ BAK-4 prisms and multicoated optics. The unit offers 13 millimeters of eye relief and a 2.7° field of view. Celestron includes a tripod adapter. The binoculars have a rubber covering and weigh 52 ounces (1.47 kilograms).
Price: $94.95
[t] 310.328.9560
[w] www.Celestron.com

5-inch telescope

Celestron
Torrance, California

Celestron incorporated Maksutov-Cassegrain optics into its 5-inch NexStar 127SLT. The go-to drive uses Celestron's SkyAlign. To set up the scope, input the date, time, and location, and slew to any three bright objects in the sky.
Price: $549.95
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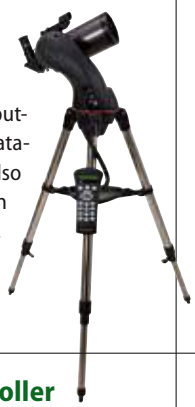
90mm go-to telescope

Celestron
Torrance, California



Celestron's NexStar 90SLT is a 3.54-inch Maksutov-Cassegrain telescope that comes with a computerized alt-azimuth mount and a database of 4,000 objects. Celestron also includes a stainless steel tripod, an accessory tray, and a finder scope.
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Short focal length refractor

Bosma Instruments
Guangzhou, China

Bosma's Beta RE is a 3.15-inch f/6.3 achromatic refractor with a 500mm focal length. It comes with 10mm and 25mm Plössl eyepieces, a 5x24 erecting finder scope, a 45° diagonal, a Baader solar filter, and a padded carrying case.
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Wireless telescope controller

Carina Software
Danville, California

Carina Software's SkyFi Wireless Adapter lets you control a go-to drive wirelessly from your Macintosh or Windows computer, iPhone, or iPod Touch. It also works with Carina's *Voyager* software running on a Mac or a PC. SkyFi runs on four AA batteries or an optional AC adapter.
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The Cosmic Grid

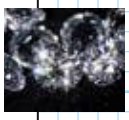
All things high, low, weird, and wonderful in astronomy and space science. **by Bill Andrews and Liz Kruesi**

WEIRD

HOT

NOT

PREDICTABLE



A diamond paradise
Because of the high pressures at Uranus and Neptune, liquid diamond oceans with floating diamond icebergs may cover the planets. Makes you wonder why we're focusing on Mars.

Armageddon out of here
The Boston Globe features a large story detailing "How to stop a killer asteroid." We thought the plan was just: 1) Call Bruce Willis, 2) Play some Aerosmith, 3) Celebrate.

Shades of blue
After seeing the 3-D epic *Avatar*, some moviegoers feel depressed about the state of Earth compared to Pandora.

ISS: You're-in trouble
High concentrations of calcium in astronauts' urine clog up the water recycler on the International Space Station.

Conundrum conference
A group of scientists meet to discuss questions they hope to solve, as well as their craziest scientific dreams and worries for the next 9 decades. What can be crazier than dark energy and string theory?

Disco tech
The light pollution in Paris is so bad, a local artist decides to simulate starlight with a huge disco ball. Oh sure, they do it, and it looks classy; we do it, and it's the 1970s.

$$N = R^* \times f_p \times n_e \times f_e \times f_i \times f_c \times L$$

From Drake's to Dates
A U.K. grad student modifies the Drake Equation to calculate the odds of finding a girlfriend. That means he's still single, ladies!

Solo sleeper
ThinkGeek offers a sleeping bag shaped like a Tauntaun, the beast Han Solo slept inside to keep from freezing. The sleeping bag fits only one, though. Perfect! After all, it wasn't Han Duo.

Lunar loss
Hawaiians find the Moon rocks previously thought lost; apparently, the Brady Bunch had to return them because of all the bad luck they'd been having.

Shuttles shuttered
NASA slashes the price on its space shuttles from $42 million to $28.8 million each. Looks like it's really a buyer's market for these things now.

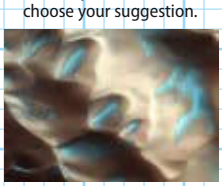
Jean-Luc Piccolo
The Calgary Philharmonic Orchestra performs "*Star Trek*: The Music," with audience-members welcome to wear costumes. Maybe those pointy ears can help you hear the music better.

Travel companion
In February, astronauts carry two rocks — one from Mount Everest and one from the Moon — to the International Space Station. Everyone likes the buddy system.

Cold thing to do
Six of the 18 mirror segments on NASA's James Webb Space Telescope have passed a big test: When they reach cryogenic temperatures, they change shape to a specific optical configuration.

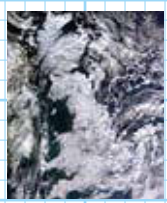
Tweet dreams
NASA holds "tweetups," where selected Twitter followers are invited to tour NASA headquarters and watch a shuttle launch. Finally, a reason to join Twitter.

Pixels you pick
Ever wish you could point the HiRISE camera to any spot on Mars and image it in extreme detail? Well, now you can. But first, make sure it's scientifically important, give it a good title, and then hope the scientists choose your suggestion.

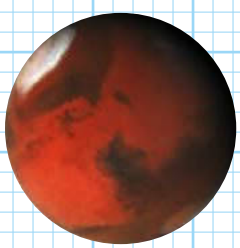


Space-wide web
The Internet is now available on the International Space Station. What's the first thing an astronaut did with the new access? Tweet.

Winter Engle-land
NASA satellite photos from January 7 show Britain entirely covered with ice and snow. Apparently ol' Mother Nature doesn't care how sophisticated ya are.

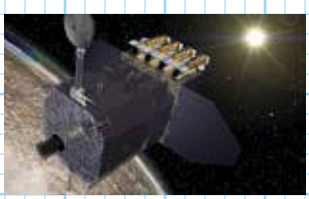


Fight of the film physicists
The Institute of Physics blog hosts a survey to find "your favorite film physicist." They have some good choices, but where's Charlie from *Top Gun* and Capa from *Sunshine*?



Big hype on Mars life
Scientific American reports proof of martian life "to come this year." Well, it's about time!

Penniless project
A recent National Research Council report says NASA can't discover 90 percent of near-Earth objects over 460 feet (140m) by 2020, as Congress asked it to do. The reason? Lack of funding.



NASA's new direction
NASA's 2011 budget points the agency toward more scientific research and robotic exploration. Doing more with the money allotted ... that sounds like advice more government agencies should listen to.

What's shaking at NASA?
The new congressional budget encourages private companies to get astronauts into space, and NASA might pull the plug entirely on manned space flight.

PHOTOGRAPHS: ©iStockphoto.com/jamesbenet (A diamond paradise); Don Davis, NASA (Armageddon out of here); ThinkGeek (Solo sleeper); NASA Johnson Space Center (NASA-JSC) (Travel companion); Photos.com (Shades of blue); NASA (ISS: You're-in trouble); *Astronomy*: Roen Kelly (Conundrum conference); Michel de Broin (Disco tech); NASA (Lunar loss); NASA (Shuttles shuttered); NASA/MSFC/Emmett Givens (Cold thing to do); NASA (Winter Engle-land); NASA (Big hype on Mars life); Photos.com (Penniless project); NASA Johnson Space Center (NASA-JSC) (What's shaking at NASA?); NASA/JPL/University of Arizona (Pixels you pick); NASA Johnson Space Center (NASA-JSC) (Tweet dreams); ©2009 Jupiterimages Corporation (Space-wide web); NASA/Goddard Space Flight Center Conceptual Image Lab (NASA's new direction)

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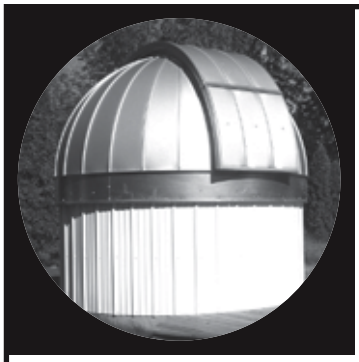

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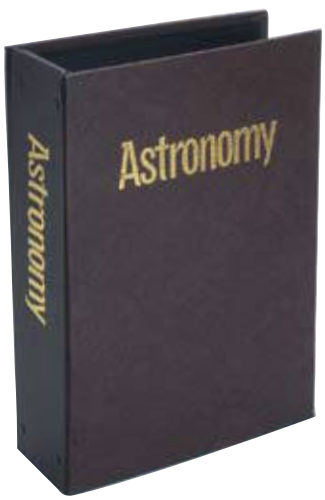

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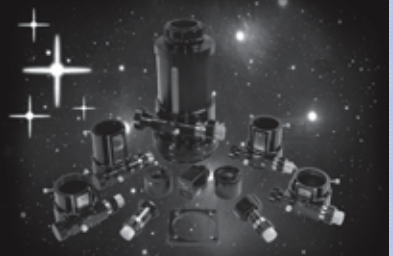

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INDEX of ADVERTISERS

Adorama 17
ALCon 2010 13
APMAmerica 65
Ash Manufacturing 65
Astro Haven 66
Astro-Physics 68
Astrocrumb's Filterslides 66
Astrodon 66
Astronomics 5
Astronomy.com 63
Astronomy Binders 67
Astronomy magazine 17
Astronomy Sweepstakes 10
Astronomy Technologies 65
Astrosystems 66
Atlas of the Stars 66
CCDWare LTD. 9
Celestron 3
Denkmeier Optical 66
Equatorial Platforms 68
Fishcamp Engineering 66
ISTAR Optical 68
Jewelry Designs for Men 67
Kahn Scope Centre 68
Knightware 67
Let's Talk Stars 68
Lightbuckets.com 17
Lumicon 65
LVI Cameras 13
Majestic Optical Coatings 68
Meade Instuments Corporation 74
Night Vision Astronomy 13
Observatory, Inc., The 67
Oceanside Photo & Telescope 65
Optic Wave Laboratories 66
Optical Mechanics, Inc. 68
Orion Telescopes & Binoculars 4
Pro-Com Electronics 66
Quantum Scientific Imaging, Inc. 13
Rainbow Symphony 66
Santa Barbara Instrument Group 2
Scope Buggy 68
ScopeStuff 66
SCS Astro 68
Sky Shed 68
SmartAstronomy.com 67
Sofia, Jim 66
Starlight Instruments, LLC. 67
Stellarvue 67
Teaching Company, The 7
Technical Innovations 9
Tele Vue Optics, Inc. 73
Telegizmos 66
TravelQuest International 67
Wood- Wonders 68
Woodland Hills Cameras and Telescopes 99
www.bigbinoculars.com 66

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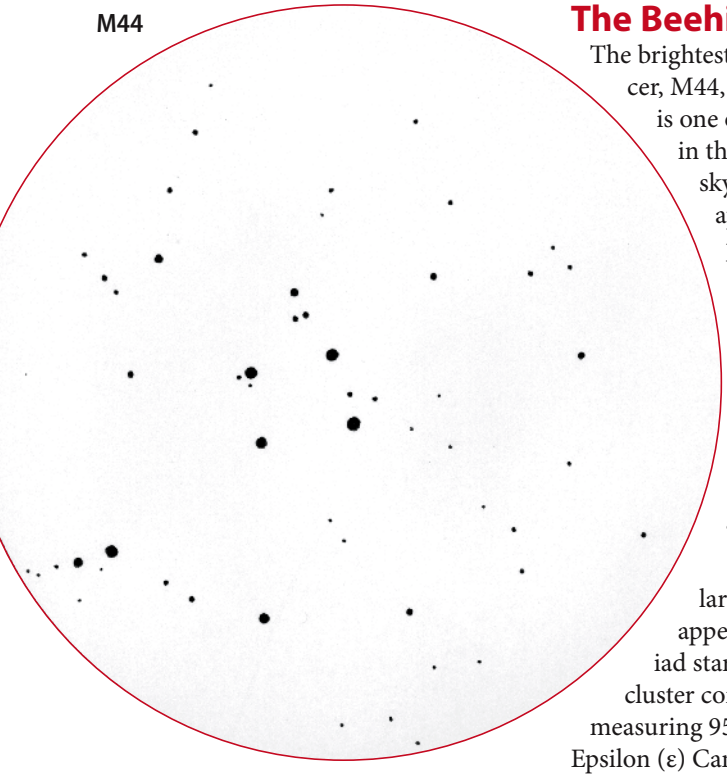
Deep-sky Showcase

Astronomy's editor sketches two of his favorite objects. **by David J. Eicher**

The Beehive and a hot galaxy



The Beehive Cluster, sketched by David J. Eicher using an 8-inch f/5 SCT at 40x.

The Beehive Cluster (M44)

The brightest deep-sky object in Cancer, M44, called the Beehive Cluster, is one of the great open clusters in the sky. Visible under a dark sky without optical aid, M44 appears as a large, hazy patch of light containing a few bright stars. Because of its naked-eye visibility, M44 was known as a weather forecaster in antiquity: Aratus called it the "little mist" as far back as 260 B.C., and Hipparchus called it the "little cloud" in 130 B.C.

Through 7x50 binoculars, the Beehive's nebulous appearance vanishes, and myriad stars become visible. The cluster contains 50 stars in an area measuring 95' across. The brightest is Epsilon (ε) Cancri, a 6th-magnitude A-type star. The most noticeable feature of M44 in a small scope is a trapezoid of magnitude 6.5 stars at the cluster's heart. Small scopes show this feature prominently. Viewed with 10-inch or larger scopes, the Beehive begins to lose its clustered appearance, and it becomes a dull object. Perhaps the instrument best suited for the Beehive is a 4-inch scope with a low-power eyepiece.

M44

Richard McCoy

Designations: M44, NGC 2632
Position: 8h40m, 19°41' (2000.0)
Constellation: Cancer
Magnitude: 3.1
Size: 95'
Distance: 577 light-years

NGC 2403

Adam Block/Mount Lemmon SkyCenter/ University of Arizona

Designation: NGC 2403
Position: 7h37m, 65°36' (2000.0)
Constellation: Camelopardalis
Magnitude: 8.5
Size: 21.9' by 12.3'
Distance: 11.8 million light-years

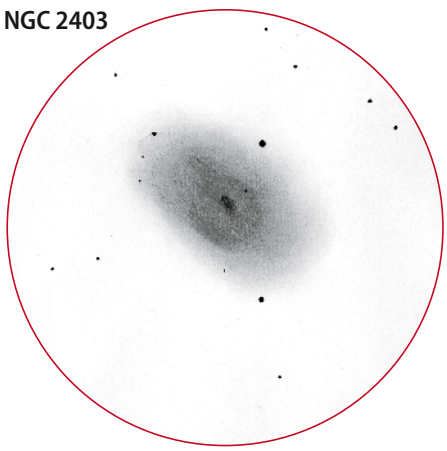
NGC 2403

Placed near two 6th-magnitude stars in the southeastern corner of Camelopardalis is the magnitude 8.5 galaxy NGC 2403. This magnificent spiral lies only 11.8 million light-years away, and it is a member of the same group of galaxies that holds M81 and M82 in Ursa Major.

Because it is relatively near and appears roughly face-on, NGC 2403 presents intricate detail in its spiral arms. This galaxy's structure resembles that of M33 in Triangulum. Both show loose, mottled patches of bright and dark nebulosity in their arms.

An 8-inch scope reveals faint mottling in this galaxy's spiral arms, and the overall object appears as a bright oval nebulosity surrounded by a dim haze. Backyard telescopes in the 16-inch class, especially when used with a nebular filter, show the patchy distribution of light in the galaxy's spiral arms with ease. Pan around the field to see patches of light strewn about.

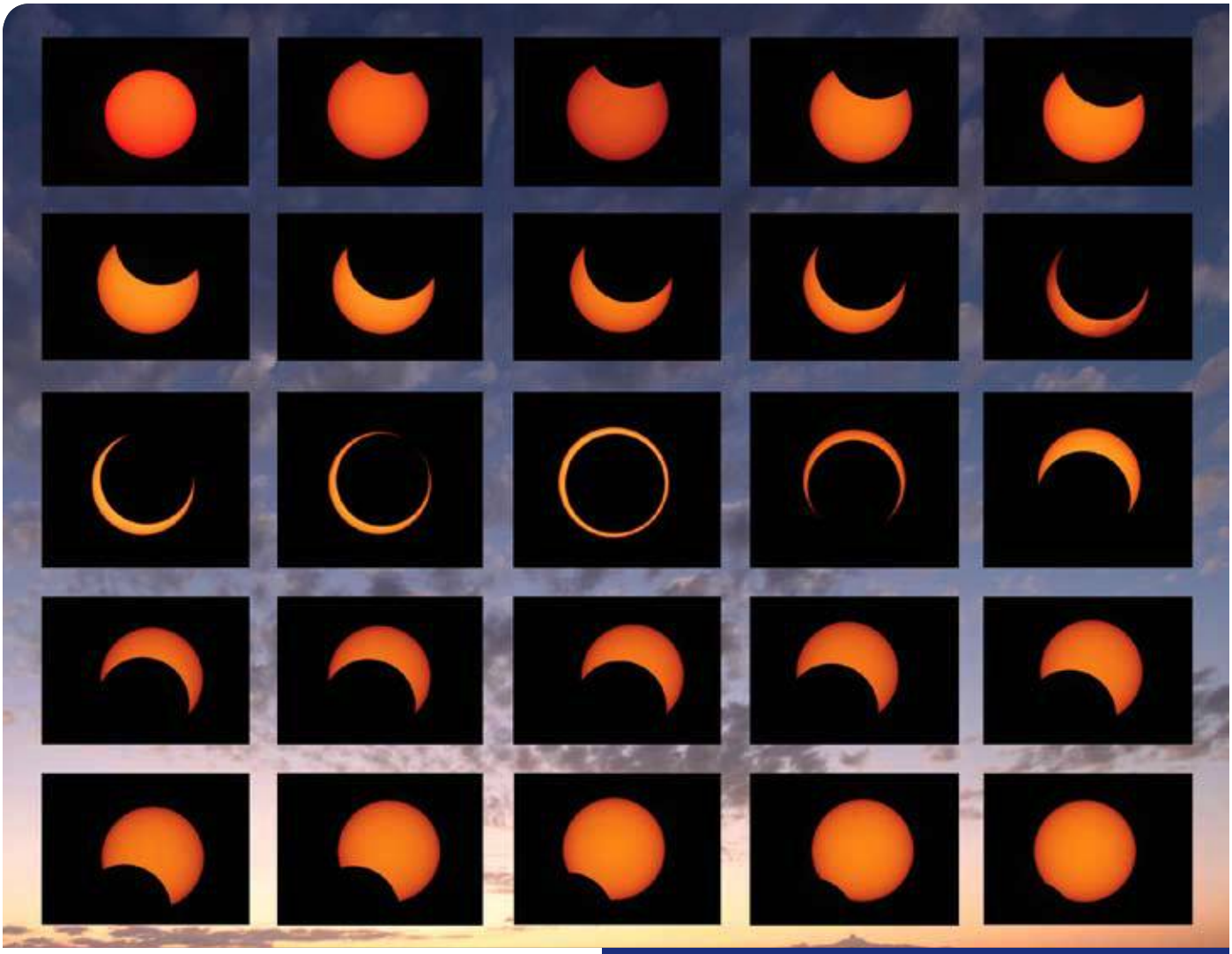
NGC 2403



NGC 2403, sketched by David J. Eicher using a 17.5-inch f/4.5 reflector at 71x.

David J. Eicher *is the editor of* Astronomy. *He has observed and sketched deep-sky objects for 34 years.*

reader gallery



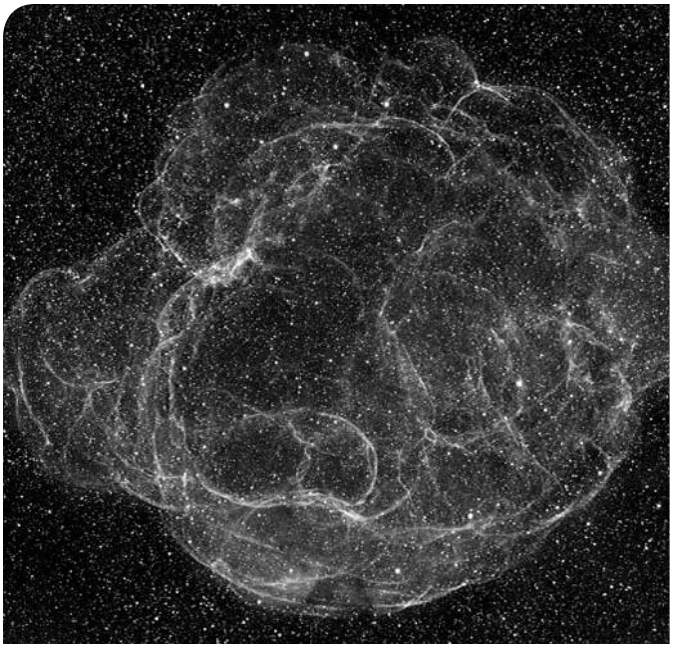
Eclipse montage (Canon 500D digital SLR, 70-300mm lens set at 300mm and f/5.6 with a 1.4x teleconverter, ISO 100, Thousand Oaks solar filter, 1/200-second images, taken January 15, 2010, from Laikipia Plateau, Kenya) • Joo Beng Koh, Singapore

Ring around the Sun

On January 15, an annular eclipse traced a thin path through parts of Africa, the Indian Ocean, and Asia. An annular eclipse occurs when the Moon lies far from Earth. During the maximum eclipse, therefore, the Moon doesn't cover the entire Sun. A ring (the Latin word is *annulus*) of sunlight remains.

During this eclipse, the Moon's diameter was 92 percent that of the Sun, so it covered roughly 83 percent of the solar disk. Because of favorable weather forecasts and the chance to participate in wildlife safaris, Kenya was the choice of many eclipse-chasers.

▶ **The Blue Oyster** (NGC 1501) in Camelopardalis is a magnitude 11.5 planetary nebula measuring 52" across. Its central star glows faintly at magnitude 14. (12-inch Meade LX200R catadioptric telescope at f/10, SBIG ST-10XME CCD camera, RGB image with exposures of 50, 35, and 45 minutes, respectively) • Ruben Kier, Orange, Connecticut



Supernova remnant Sharpless 2–240 lies in Taurus. This nearly circular object spans 3.8°. (4-inch Tele Vue NP-101is apochromatic refractor at f/5.4, SBIG STX-16803 CCD camera, forty-three 8-minute exposures through a Hydrogen-alpha filter) • Jim Burnell, Warwick, New York

Open cluster M25 in Sagittarius is one of Messier's lesser-observed objects. It glows at a magnitude 4.6 and measures 32' across. It's tough to see without optical aid because of the richness of the background. (14.5-inch RC Optical Systems Ritchey-Chrétien telescope at f/7.9, SBIG STL-11000 CCD camera, ten 90-second exposures through L, R, G, and B filters) • Richard Hammar, Springfield, Missouri

Spiral galaxy NGC 1961 in Camelopardalis has asymmetric arms that appear highly disturbed. Vast areas of star formation lie in this galaxy. (24-inch RC Optical Systems Ritchey-Chrétien telescope at f/8, SBIG STL-11000 CCD camera, LRGB image with exposures of 135, 60, 40, and 50 minutes, respectively) • Adam Block, Mount Lemmon SkyCenter, University of Arizona

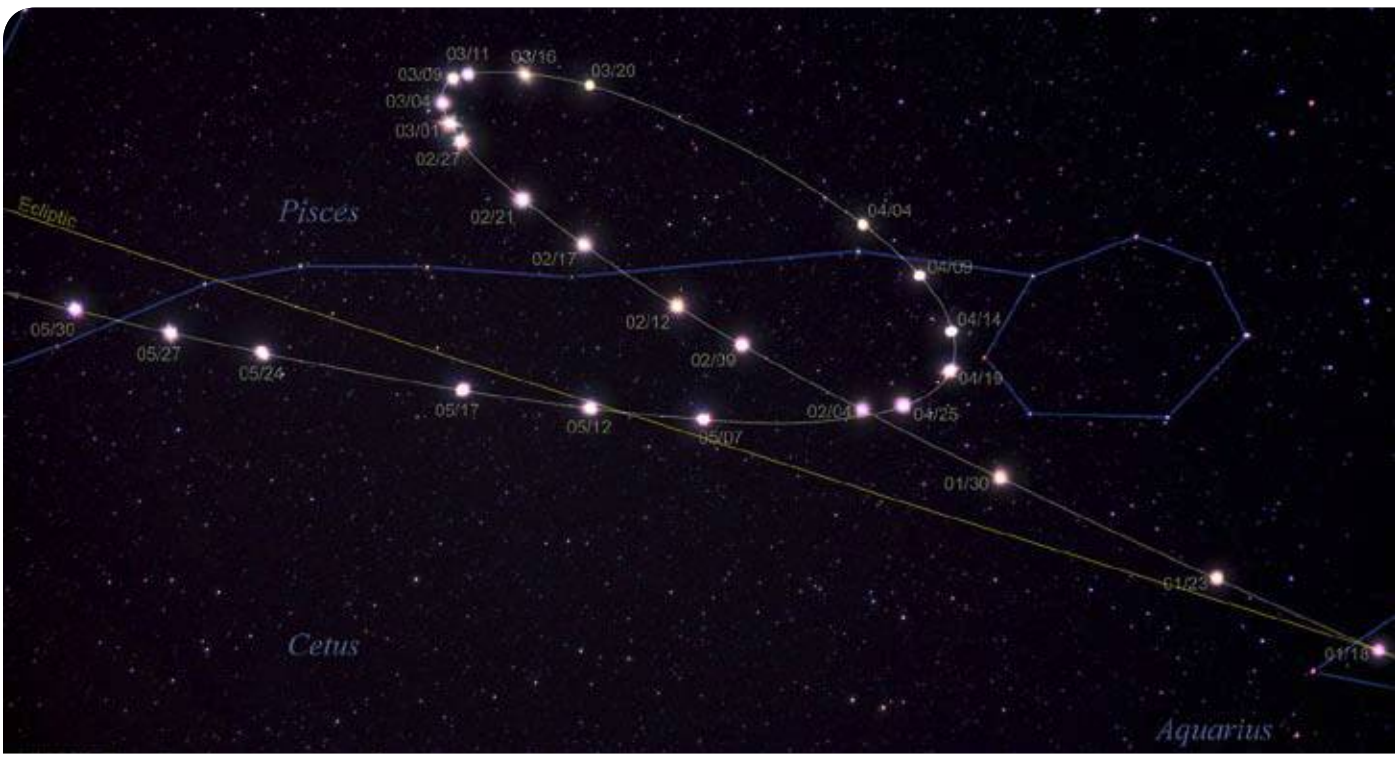
▶ **Orion's Belt** is one of the most recognizable star patterns in the sky. A long-exposure image, however, provides quite a different view than that through our eyes alone. (4-inch Takahashi FSQ-106 EDX refractor at f/3.6, SBIG STL-11000 CCD camera, LRGB image with exposures of 2.5, 1, 1, and 1 hour, respectively) • Rogelio Bernal Andreo, Sunnyvale, California

reader gallery

Send your images to: *Astronomy* Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, and exposure information. Submit images by e-mail to readergallery@Astronomy.com.

Above: Venus travels through Pisces in this series of images from the first half of 2009. The photographer processed all Venus images so as to cancel out the differences caused by various exposure times. (Planet images: Canon EOS 5D digital SLR, 50mm f/1.8 lens set at f/2.8 or 35mm lens at f/2, various ISO settings and exposure times, 26 images from January 18 through May 30, 2009) • Tunç Tezel, Bursa, Turkey

Below: This annotated image shows the dates of the images, and it highlights the background constellations through which Venus moved. For several of these exposures, the imager had to photograph through clouds. The width of this image spans approximately 40°. (Background image: Canon EOS 5D digital SLR, 50mm f/1.8 lens set at f/2.8, ISO 1600, 30-second exposure) • Tunç Tezel, Bursa, Turkey



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